THE AMERICAN SURGEON

Vol. 24, No. 6 June, 1958

FOREWORD

The University of Texas Southwestern Medical School is one of the newest of the medical schools, evolving to its present development since the spring of 1943. In the winter of 1943 Baylor Medical School, which had long been in Dallas, made the decision to move to Houston. Several years earlier, in 1939, a group of lay and medical leaders in Dallas had formed Southwestern Medical Foundation for the purpose of providing support for medical education and research in the Southwest. When it became evident that the city would soon be without a medical school, the Southwestern Medical Foundation, under the leadership of its President, the late Dr. Edward H. Cary, decided to establish a new institution to be called "Southwestern Medical College of Southwestern Medical Foundation."

When this decision had been finally made, a faculty was assembled which included many of the faculty of the Baylor school whose homes had long been in Dallas and who elected to remain. These men and women, together with numerous experienced clinical physicians in Dallas, provided an excellent and well qualified teaching group to begin operations in July of 1943. Many medical students also elected to remain and continue their education in the newly chartered school.

The problem of providing physical space for laboratories and classrooms was temporarily solved during the first summer by use of a city high school. Books, journals, microscopes and much other vital equipment were made available by donations from doctors and from other professional and scientific groups in Texas and neighboring states. Clinical teaching, under the usual clerkship methods, took place in the city's hospitals, more especially in Parkland Hospital of the City and County of Dallas. During the months of July and August arrangements were made and priorities obtained for the construction of an extensive series of temporary wooden buildings which were erected upon land made available from the City of Dallas adjacent to Parkland City-County Hospital. With outstanding community support, the temporary facilities were completed in September 1943, in time for the opening of the fall term.

The medical school continued to operate and develop as an approved school of medicine under the auspices and support of Southwestern Medical Foundation until September 1, 1949, when it became a part of the University of Texas, under the authority of a statute of the 51st Legislature which provided that the University of Texas might acquire or develop a second medical school in addition to the long existent one at Galveston. One of the provisions of the law was that the location of the second school should be recommended by the House of Delegates of the Texas State Medical Association. The law also provided that the University might acquire already existing facilities. The House of Delegates of the Texas Medical Association met and formally recommended that the University begin negotiations to acquire Southwestern Medical College and to establish its second medical school in Dallas. As a part of the basic agreements, the Foundation transferred to the University of Texas the physical properties, equipment, library and approximately 68 acres of valuable land upon which to continue to develop the medical school. Since September 1, 1949, then, the University of Texas has owned and operated Southwestern Medical School as a part of the University System. Southwestern Medical Foundation continues in existence and provides additional support in the form of annual and special grants to the University for teaching and research in medicine at Southwestern Medical School.

The 1951 session of the Texas Legislature appropriated funds for the construction of the first of the permanent buildings and in January of 1955 the present basic science building was occu-

pied. In 1954 a special session of the Legislature again considered the physical plant requirements and provided further monies, for a second building to meet the needs of the clinical departments of the school of medicine. This second structure, currently nearing completion, is continuous with the previously constructed basic science building and has tunnel access to the new Parkland Memorial Hospital, which is the principal teaching hospital for the school. This splendid new facility, owned and governed by the Dallas Hospital District, is a general hospital of 588 beds and 72 bassinets and is the main unit in a system which contains, additionally, 60 beds for psychiatric care, approximately 200 beds for tuberculosis and about 100 beds for chronic diseases of the aged and infirm. This modern and well equipped hospital system makes available the very best in patient care and teaching facilities in a program closely oriented with the work of the medical school. Baylor, St. Paul's and Methodist Hospitals also participate with Parkland Memorial Hospital in the program of medical education and make certain special teaching services available for small groups of students. Two nearby Veterans Administration Hospitals operate as Dean's Committee hospitals and increase the facilities for both undergraduate and postgraduate teaching. These, together with the Children's Medical Center which is a complex of general pediatric beds with infant hospitals and a crippled children's hospital, allow for a well rounded clinical program.

Fairly early in the evolution of the new medical school it was decided to plan for a nucleus of full-time personnel in all departments. It was felt that such a group, supplemented and strengthened by the large reservoir of highly qualified and experienced clinical faculty in the community, offered the greatest opportunity for a well coordinated teaching and research program. Full-time faculty at all levels now numbers 91 and the part-time clinical faculty, 619.

The Medical School and the Department of Surgery are indeed honored in being asked to contribute the contents of an issue of the AMERICAN SURGEON. In the historic development of the school, the Department of Surgery has been similar to other departments in the gradual acquisition of the nucleus of full-time personnel, now numbering 7 full-time persons from professor through instructor. The full-time department members, as in the other departments, are assisted by a distinguished group of part-time clinical members, numbering 186.

The Professor and Chairman of the Department of Surgery, Dr. Ben J. Wilson, also directs the following Divisions listed with their respective Chairmen: Neurosurgery, Dr. William Kemp Clark; Ophthalmology, Dr. Carroll W. Browning; Oral Surgery, Dr. P. E. Williams; Orthopedic Surgery, Dr. Charles F. Gregory; Otolaryngology, Dr. Claude De Winborn; Proctology, Dr. Curtice Rosser; Thoracic Surgery, Dr. Hugh E. Wilson; and, Urology, Dr. Harry M. Spence.

The Department of Surgery and its several specialty Divisions have already participated in the training of many young men and women, and with each year the training and research programs at all levels expand to meet the ever increasing needs of our region and the country as a whole.

A. J. GILL, M.D., Dean
The University of Texas
Southwestern Medical School
Dallas, Texas

INJURIES OF THE URETER DUE TO EXTERNAL VIOLENCE

HARRY M. SPENCE, M.D., AND THETFORD B. BOONE, M.D.

Dallas, Texas

Most ureteral injuries result from surgical accidents at the time of extensive gynecologic operations within the pelvis, although they may occur during urologic operations on the ureter, and at times may accompany abdominoperineal resection of the rectum. Occasionally instrumental perforation of the ureter results from cystoscopic manipulation such as perforation with the stone basket. Rarely the ureter is injured from external violence, chiefly gunshot, stabbing or orthopedic injuries. In this paper we wish to consider the latter class and shall present five such cases from the Surgical and the Urological Services of Parkland Hospital.

THE LITERATURE

Most current articles on traumatic ureteral injuries from external violence deal with experiences in battle casualties. From these reports certain principles and conclusions emerge which are valid in the management of comparable lesions in civilian practice. These will be reviewed.

Incidence. In their comprehensive review of injuries to the genitourinary organs occurring in the European Theater of Operations in World War II, Robinson and associates[4] included 25 cases of wounds of the ureter. Culp,[2] in 160 cases of urogenital injuries under his personal supervision, encountered only 6, or 3.75 per cent involving the ureter. On the civilian side Rusche and Hager[5] present 103 cases of all types of ureteral injuries occurring over the 20-year period ending in 1950 and found 9 due to external trauma (7 gunshot, 2 automobile accidents).

Other series, in general, parallel this low incidence which is attributable to the small size and protected course of the ureter.

Associated injuries. All observers agree that the great majority of ureteral wounds are accompanied by damage to adjacent structures, chiefly the intraperitoneal organs. In the Robinson series only 2 out of 25 patients failed to have other injuries. The practical importance of this fact is that the concomitant injuries more often than not dominate the clinical picture so that unless the surgeon has a high index of urologic suspicion, the ureteral injury will be overshadowed if not completely overlooked to the subsequent detriment of the patient. Admittedly, a perforated abdominal viscus takes precedence in treatment, yet whenever feasible, repair of ureteral damage or at least adequate drainage at the initial operation, is most desirable.

Diagnosis. Despite their infrequent occurrence the possibility of a wound of the ureter should be entertained when the penetrating object traverses the ureteral areas or when extreme external violence is sustained in the flank or pelvis. Only by so doing will these cases be detected early when one is afforded his best chance to do a definitive restoration of the ureteral continuity. In addition to the more obvious visceral injuries the inherent difficulty in early recognition of ureteral damage lies in the fact that signs and symptoms tend to be latent. Contrary to the situation in the patient with a ruptured kidney or bladder where hematuria is abundant and/or extravasation soon evident, the bleeding in a ureteral wound tends to be minimal or absent and evidence of extravasation develops slowly and insidiously over a period of days rather than hours.

When ureteral trauma is suspected, if the patient's general condition permits, an excretory urogram may give the desired information, or if inconclusive, cystoscopy and retrograde pyelography may be relied upon to demonstrate ureteral integrity or lack thereof. Most often, however, the job of the moment in the critically injured patient is to save his life, so immediate exploratory laparotomy is indicated. This should include, at an appropriate moment, a survey of the ureteral course looking for urinary leakage or laceration of the ureter itself.

In the majority of reported cases preoperative urologic study was not carried out, nor was the injury noted at the time of surgical exploration. The usual course under these circumstances is for the lesion to manifest itself only after a period

From the University of Texas Southwestern Medical School, Parkland Memorial Hospital, and the Dallas Medical & Surgical Clinic, Dallas, Texas.

of days to weeks by (1) urine draining from the wound of entrance or exit or from the surgical incision, (2) urinary ascites or (3) a closed accumulation of extravasated blood and urine, often infected.

At this latter stage also, study starts with the excretory urogram supplemented by ureteral catheterization and retrograde study to determine (1) the site of the injury, (2) whether partial or complete transection exists, (3) the condition of the kidney on the involved side and (4) the state of the opposite kidney. Positive urographic findings are shown in the illustrations in our cases, with impaired function and hydronephrosis of varied degree above the site of injury and extravasation of the opaque urographic media being typical.

Treatment. The aim of treatment is restoration of ureteral continuity and integrity and preservation of the kidney. This is determined largely by the time of recognition and the level and extent of the injury. If detected at the initial operation and if transection of the ureter is complete, an end-to-end suture of the freshened edges over a splinting catheter is generally recommended for an upper segment injury and reimplantation into the bladder if the injury is in the lower segment.

If the ureter is only partially divided so that a strip of longitudinal wall remains intact, or only a window is missing, splinting by catheter with or without suture of the defect, is the procedure of choice. In either instance extraperitoneal drainage is mandatory since the closure is not likely to be watertight.

Even when not detected immediately and when urinary drainage from either the external wound or the surgical incision during convalescence first announces a ureteral injury, identical attempts at restoration are indicated. Indeed if a ureteral catheter can be passed to the kidney by cystoscopic manipulation, this indicates only partial severance of the ureter, and leaving such a catheter indwelling for a number of days plus surgical drainage of any extravasated fluids may suffice. Most often, however, in a case diagnosed late, retroperitoneal sepsis or frank abscess formation with retraction of the ureteral ends precludes primary end-to-end anastomosis, so that drainage of the area plus diversion of the urine from the kidney by nephrostomy is necessary with later attempts at reconstruction in a relatively clean field. The turning upward of a bladder flap or even the use of an ileal segment substitution should be considered before nephrectomy in such a case although for practical purposes the latter may eventually be justified to rehabilitate a devitalized patient. An important final phase of the treatment consists of systematic follow-up with cystoscopic dilations as required to prevent late stricture formation at the anastomotic site.

Results. On reviewing the reported experience with ureteral injury of the type under discussion, one gets the following impressions: (1) If the ureter is only partially divided, a satisfactory outcome may be anticipated. Thus, of Culp's 6 cases, 3 had only partial tears and all healed satisfactorily with simple indwelling catheters. (2) Early end-to-end anastomosis of the upper ureter or implantation of the ureter into the bladder for a lower segment injury, may terminate successfully although failures both immediate and delayed occur in a significant number requiring nephrectomy. (3) In the cases recognized late, reconstructive surgery is much less likely to be successful although an occasional gratifying result makes such efforts here still decidedly worthwhile.

Henkel,[3] in discussing Korean battle casualties, summarized the situation well when he stated, "There is no other group of cases among urologic injuries that present as much difficulty in early diagnosis and have given such poor results with later surgery," and further "whether a stricture develops or not depends . . . to a considerable degree on Fate."

Of the nine civilian injuries reported by Rusche and Hager, one died the second day. Four cases came to nephrectomy either immediate or late. One refused treatment and ended with a nonfunctioning kidney. Three ended successfully, one with ureteral catheter drainage, one after ureteroneocystostomy, although the kidney was noted to be hydronephrotic, and one recovered after incision and drainage.

From the above it would seem that considerable study and work remain to be done in an effort to improve the long term results of injuries to the ureter due to external violence.

CASE REPORTS

Case 1. PMH W23703. A 23-year-old man was admitted to the Emergency Room at Parkland Memorial Hospital on July 12, 1952, shortly after having been accidentally shot in the abdomen with a .22 caliber rifle. Examination revealed a

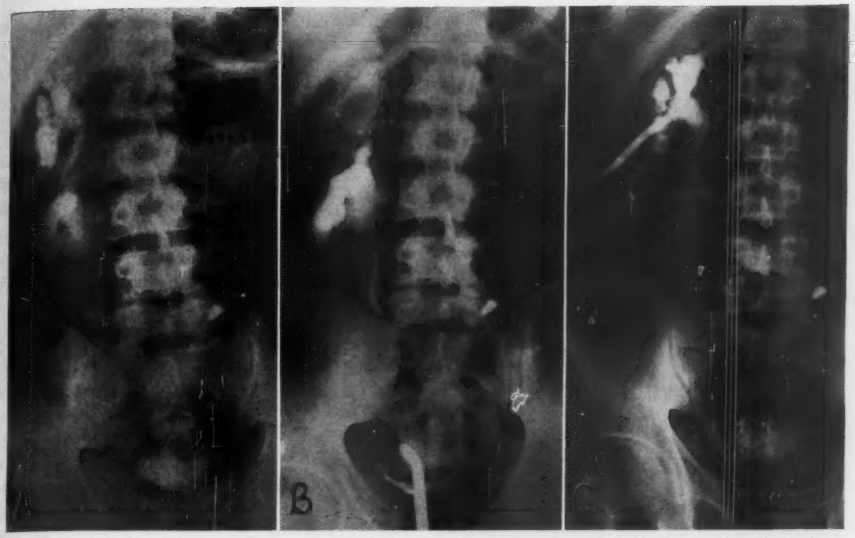

FIG. 1. Case 1. (*A* and *B*) Intravenous and retrograde urograms showing hydronephrosis and extravasation of dye 5 weeks after initial injury and "blast" necrosis of leakage. (*C*) Pyelo-ureterogram made by injecting dye through nephrostomy tube after removal of splint. This shows an immediate good result but subsequent stricture resulted in loss of kidney.

husky Latin-American in profound shock with evidence of peripheral vascular collapse. Blood pressure was 60/40, pulse 140, respirations 18 and quite shallow. The wound of the bullet's entrance was in the right anterior axillary line at the level of the 10th rib with no wound of exit noted. The patient vomited 750 cc. of blood. A Foley catheter was inserted, obtaining bloody urine.

On account of the precarious state of the patient, laparotomy was carried out as soon as antishock measures had been instituted. Under general anesthesia through a supraumbilical transverse incision the abdomen was opened and 700 cc. of fresh blood were found within the peritoneal cavity. There was evidence of a large retroperitoneal hematoma as well as a penetrating wound of the liver, a through-and-through perforation of the gallbladder and third portion of the duodenum. The wounds of the duodenum were closed and a cholecystectomy done. The posterior peritoneum was opened, upon which there was a large gush of blood estimated at 3 L. and found to come from an extensive laceration of the inferior vena cava below the renal vein. The cava was ligated with umbilical tape. The ureteral areas were exposed and no evidence of injury noted. A sump drain was placed in the retroperitoneal sac, Penrose drains to Morrison's pouch and additional Penrose drains to the right retroperitoneal area. The patient was delivered to the recovery room in extremely poor condition.

Postoperatively the patient did surprisingly well. His urinary output was adequate and soon became clear of blood. All drains were removed on the sixth postoperative day when for the first time considerable drainage of clear fluid was noted from the retroperitoneal sinus tract accompanied by a spiking fever of 102°F. Except for this the patient was asymptomatic and was discharged from the hospital on the 21st postoperative day.

Two weeks thereafter he was readmitted on account of profuse urinary drainage from the retroperitoneal sinus accompanied by pain in the lumbar area. An excretory urogram now (5 weeks after the initial injury) revealed extravasation of dye (fig. 1*A*). Retrograde pyelograms were attempted but the ureteral catheter met an impassable obstruction 14 cm. above the bladder (fig. 1*B*). The left kidney appeared normal. A diagnosis of ureteral injury was evident, and on August 18, 1952, under general anesthesia, through a flank incision the right kidney and ureter were explored. The procedure was extremely difficult due to dense inflammatory adhesions but eventually the ureter was exposed and in the area opposite the 3rd lumbar vertebra a longitudinal defect 4 cm. in length was noted with a mere strand of tissue representing the remnant of the ureteral wall. Since it was obviously impossible to join the two ends of healthy ureter the defect was splinted and a nephrostomy done. The splint used was a no. 8

red rubber catheter passed through the nephrostomy wound and extending the entire length of the right ureter.

The immediate course following the ureteral reconstruction was satisfactory, but on the 15th postoperative day he developed closed loop intestinal obstruction and required laparotomy to release a mechanical obstruction of the ileum due to adherent bands. Recovery from this was smooth.

Six weeks after the ureteral intubation had been done the splint was removed, and opaque material injected through the nephrostomy tube demonstrated excellent continuity of the ureter without evidence of extravasation (fig. 1*C*). Despite this early satisfactory result, however, the patient in the next few weeks began to develop significant temperature elevation and on November 6, 1952, a stricture had developed at the 21-cm. level which defied repeated attempts at catheterization and dilation. Antegrade pyelography through the nephrostomy tube which had been left in place on removal of the splint demonstrated a large abscess cavity in which the dye and urine drained. The patient was now weakened by sepsis and it was felt that his best interest would be served by nephrectomy which was carried out on December 1, 1952. A normal convalescence followed.

Comments. (1) Although a ureteral injury was suspected and looked for at the time of the original laparotomy it was not apparent and only showed up fairly late in the convalescence. In all likelihood it was due to necrosis of the "blast" type. (2) The technical difficulty of anastomosing the separated ends of the ureter at the reconstructive procedure was overcome by the principle of the intubated ureterotomy with a good immediate result, but subsequently a stricture formed which could not be overcome by cystoscopic maneuvers and eventuated in the loss of the kidney.

Case 2. PMH 104677. This 23-year-old Latin-American man was shot in the lower abdomen with a .22 caliber rifle on May 9, 1953, sustaining five perforations of the jejunum and one in the bladder as determined at an exploratory laparotomy shortly after arrival at the hospital. The jejunal perforations were closed and a suprapubic cystotomy performed with drains to the prevesical space.

The patient had an uneventful immediate convalescence but on the sixth postoperative day a fecal fistula developed at the site of one of the gunshot wounds requiring re-exploration and a colostomy for fecal diversion. Following this the patient did well until the ninth postoperative day, when urine began to drain from the distal colostomy loop. Indigo-carmine injected intravenously appeared from the rectum and also from the distal colostomy stoma, so a vesicorectal communication was presumed to be present. It was felt, however, that additional time should be given for improvement in his general condition prior to any further surgical exploration and he was discharged to be followed in the Urology Clinic.

During the succeeding months the patient progressed well but, since urine continued to drain from the distal colostomy stoma and at times from the rectum, he was readmitted for further evaluation approximately 10 weeks after the initial injury. Studies were started by injecting methylene blue solution into the bladder to confirm the existence of a vesicorectal fistula. None of the dye so injected appeared in the rectum although indigo-carmine injected intravenously did appear therein. On cystoscopy, obstruction was met in the left lower ureter. It was felt that these findings established a diagnosis of *ureterorectal* fistula, whereupon ureteral re-exploration was carried out through a left Gibson incision. The ureter was identified as it crossed the pelvic brim and traced downward toward its insertion into the bladder. Here a great deal of induration and inflammatory reaction was encountered which apparently marked the site of the ureterorectal fistula. The ureter was divided and reanastomosed into the bladder through an oblique stab wound with a mucosa-to-mucosa approximation. No splint was used. A suprapubic catheter was left indwelling as well as Penrose drains to the operative area.

The patient recovered quite well following this procedure and was followed by his private physician who reports that the colostomy was subsequently closed. A persistent urinary tract infection was due to some bladder calculi which were removed. Following this, convalescence was uneventful, and after six months a follow-up examination, including intravenous pyelogram, showed a good postoperative result with no evidence of hydronephrosis or other abnormality.

Comment. A ureterorectal fistula is most unique.

Case 3. PMH 104980. A 27-year-old colored man was admitted to Parkland Memorial Hospital May 21, 1953, after having been stabbed five times in the left chest and abdominal area with a long bladed pocket knife. The positive findings in addition to the stab wounds of the chest and

FIG. 2. Case 3. (*A* and *B*) Retrograde studies showing clots within the ureter, hydronephrosis and dye escaping at site of partial division of ureter by a stab wound. (*C*) Normal appearance on excretion urogram 4 weeks after external drainage operation.

abdomen were intoxication, shock, tracheal deviation to the right with absent breath sounds on the left and a rigid abdomen. Only microscopic hematuria was recorded.

Immediately after admission, chest tubes were inserted on the left to relieve the tension in the thorax. Following this the abdomen was explored through a left paramedia incision. A 1-cm. perforation on the anterior aspect of the stomach was closed, as well as a rent in the jejunal mesentery. No comment was made regarding the kidneys or ureters. The patient did well until two days after operation when he developed a high fever and began to pass gross blood in the urine. An intravenous pyelogram now showed nonfunction on the left side while the right kidney appeared normal. Cystoscopy was carried out, showing a clot extruding from the left ureteral orifice. Retrograde studies (fig. 2*A* and *B*) showed mild left hydronephrosis with multiple ureteral filling defects thought to represent blood clots and an area of extravasation approximately 4 cm. below the ureteropelvic junction. On the 10th postoperative day, through a left loin incision, the lower pole of the kidney was exposed and dissection carried down in the general direction of the ureter looking for a perinephric abscess. No frank abscess or extravasation was found although the tissues about the ureter were considerably indurated. No effort was made to explore the ureter in view of the extensive inflammatory reaction, but drains were placed to the area.

Following this the patient had an uneventful convalescence from the urologic viewpoint, although an empyema required drainage. A follow-up excretory urogram was considered essentially normal on June 19, 1953 (fig. 2*C*).

Comment. The ureteral injury here was evidently partial and healed spontaneously after external drainage was provided.

Case 4. PMH 147255. This 27-year-old colored man was admitted through the Emergency Room shortly after having been shot in the left lower quadrant of his abdomen with a .22 caliber rifle. The patient was in good condition on admission, his blood pressure being 140/70, pulse 120, respirations 20. The physical examination was within normal limits except for generalized boardlike rigidity of the abdomen and a 1-cm. wound of entrance of a bullet in the left lower quadrant. No wound of exit was noted. The urine was grossly clear but microscopically loaded with red blood cells, which prompted urologic study.

A film of the kidney, ureter and bladder showed the foreign body in a position lateral to the right sacral border. An intravenous pyelogram was first

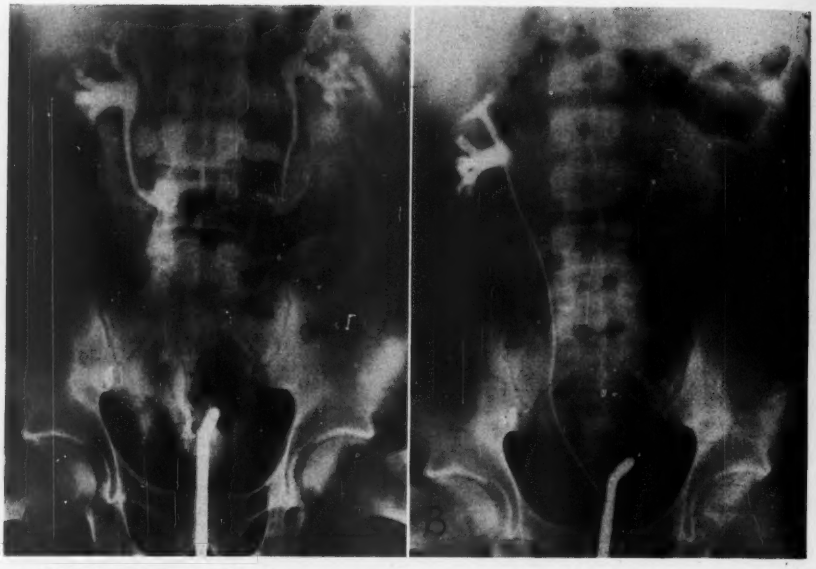

FIG. 3. Case 4. Injury to right lower ureter diagnosed preoperatively from retrograde urogram shown in (*A*). The dye seen in both kidneys represents the excretory study immediately preceding which with the microscopic hematuria directed attention to the urinary tract. (*B*) Ureteral catheter passed easily to the kidney postoperatively.

made which showed evidence of injury at the lower portion of the right ureter and a subsequent retrograde pyeloureterogram showed extravasation of contrast media at the junction of its middle and lower thirds (fig. 3*A*).

Immediately thereafter the patient was explored through a midline incision. The peritoneal cavity contained gross blood and fecal contamination. The small bowel was inspected from distal ileum proximally to the ligament of Treitz and 10 gunshot perforations were found and closed. There were numerous through-and-through tears of the mesentery. One short segment of ileum was resected because of impaired vascularity. The colon was free of injury. Attention was next directed to the right lower ureter which was readily identified and found to have been traversed through and through by the missile, leaving only strands of ureteral wall undivided. The gunshot wound to the ureter was debrided back to viable tissue and the edges approximated with 00000 silk sutures through the serosa. Multiple Penrose drains were placed to the area of injury.

The day following surgery the patient was cystoscoped and a no. 6 ureteral catheter was passed up the right side with ease and left indwelling for 19 days. The Penrose drains were removed a few days after the ureteral catheters and after the wound had become dry. The entire convalescence was remarkably smooth. Right retrograde studies were made postoperatively showing a good functional result without evidence of extravasation or stricture formation (fig. 3*B*).

Comment. Significant microscopic hematuria on admission called attention to the urinary tract and the patient's general condition permitted a most informative preoperative work-up so that definitive ureteral reconstruction was possible at the initial exploration. Splinting of the ureter at the time of surgery would have been preferable as would have been the use of absorbable rather than silk sutures to sew the ureteral rent. Phosphatic incrustation on a nonabsorbable suture makes urologists reluctant to use silk where it may be bathed by urine. The final result here reflected accurate suturing of the defect.

Case 5. PMH 164562. This 26-year-old colored man was admitted to the Surgical Service at Parkland Memorial Hospital on December 23, 1957, because of multiple gunshot wounds of the arm, chest and abdomen.

Examination revealed a moribund colored man. Blood pressure 80/40, respirations 30, pulse 120. There were rales and dullness over the right chest posteriorly. The abdomen was rigid. Examination

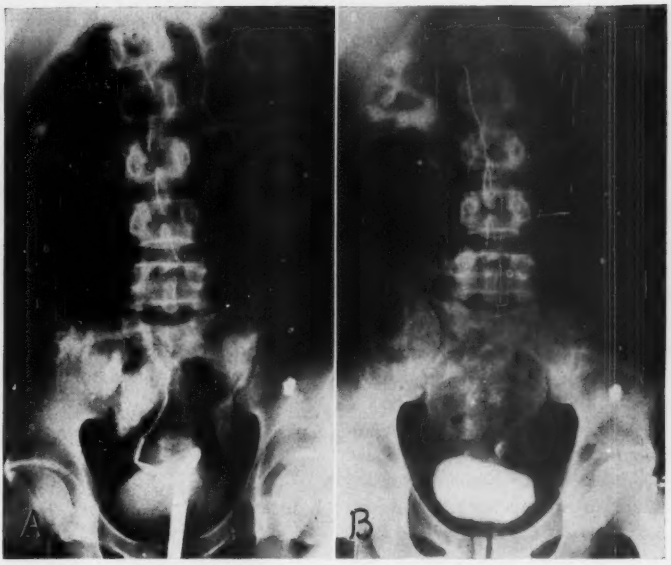

FIG. 4. Case 5. (*A*) Twelve days after end-to-end anastomosis and 3 days after removal of splint attempted retrograde study show ureteral continuity but some extravasation. (*B*) Intravenous pyelogram normal after additional indwelling ureteral catheter drainage.

of the trunk revealed two gunshot wounds over the right anterior chest, and also a wound involving the right forearm. The impression was that of multiple gunshot wounds of the chest and right arm and abdomen with a hemopneumothorax on the right. There was also evidence of intraperitoneal hemorrhage as shown by bloody fluid on abdominal paracentesis. A chest tube with a water-seal was placed in the right chest cavity and exploratory laparotomy performed. The peritoneal cavity contained 1500 cc. of blood. Eleven holes were found as the small bowel was run and these were closed individually. A large retroperitoneal hematoma resulting from a perforation of the right external iliac vein by one of the bullets was discovered. The vein was ligated. The right ureter was next explored and was noted to have been transected. Each end was identified and debrided by sharp dissection. The bladder was then opened and a no. 5 ureteral catheter passed in a retrograde fashion from bladder to kidney followed by an end-to-end anastomosis of the ureteral segments with 0000 chromic catgut. Both splinting catheter and a Foley catheter to drain the bladder were brought out suprapubically. Multiple rubber tissue drains were placed down to the area of injury.

The patient did well following surgery, and on the ninth postoperative day the ureteral catheter and suprapubic Foley catheter were removed. An attempted ureterogram done three days later showed some leakage of dye at the point of anastomosis (fig. 4*A*) so a no. 5 catheter was reintroduced by cystoscopy and satisfactorily passed the point of obstruction. The patient did well thereafter. This splinting ureteral catheter was left in place for two weeks more and again removed. The patient recovered nicely. Follow-up excretory and retrograde studies showed evidence of a functioning anastomosis with good continuity and no extravasation (fig. 4*B*).

Comment. This case demonstrates that ureteral injury is amenable to recognition and proper handling at the time of exploratory laparotomy even when the surgeon is not forewarned by hematuria or aided by preoperative urograms.

DISCUSSION

While the incidence of ureteral injuries from external violence is admittedly rare, such lesions occur sufficiently often to engage the interest of the surgeon as well as the urologist involved in the management of accident cases. Hematuria, frank or microscopic, is perhaps the most significant signpost, not only of ureteral injury but also of renal and bladder trauma and should never be

disregarded. If the patient's condition permits, an excretory urogram performed concomitantly with the inauguration of routine preoperative supportive measures may be most rewarding. Our case 4 attests to this. Even though the exigencies of the moment prevent formal preoperative urologic investigation, the operator should still think of and look for ureteral trauma as in our case 5.

Utilizing these concepts, 4 of the 5 cases in this Parkland Memorial Hospital series have had a satisfactory outcome with preservation of the kidney corresponding to the injured ureter.

CONCLUSIONS

1. Ureteral injury from external violence warrants the attention of the alert surgeon.

2. Hematuria, gross or microscopic, supplies the indication for preoperative urologic investigation if the condition of the patient permits.

3. If immediate laparotomy without benefit of urologic investigation is mandatory, the possibility of ureteral injury as well as kidney or bladder injury should be kept in mind and appropriate investigation made at the time of initial surgery.

4. Methods of repair in the early recognized case will vary with the type and site of injury. End-to-end anastomosis over a splinting catheter or reimplantation into the bladder are to be preferred when complete division is present. Splinting alone with or without external drainage may suffice in partial transection.

5. In those cases becoming manifest late, external drainage with subsequent reconstructive measures may result in salvage of the kidney in an appreciable number.

REFERENCES

1. Clarke, B. G., and Leadbetter, W. F.: Management of wounds and injuries of genito-urinary tract: a review of reported experience in World War II. J. Urol., *67:* 719, 1952.
2. Culp, O. S.: War wounds of the genito-urinary tract. J. Urol., *57:* 1117, 1947.
3. Henkel, H. B.: The urologic battle injury in the Korean conflict. J. Urol., *70:* 637, 1953.
4. Robinson, J. N., Culp, O. S., Suby, H. I., Reiser, C. W., and Mullenix, R. B.: Injuries to the genito-urinary tract in the European theatre of operation. J. Urol., *56:* 498, 1946.
5. Rusche and Hager, B. H.: In *Urology*, ed. by M. F. Campbell. W. B. Saunders Co., Philadelphia, 1954, p. 906.

A REVIEW OF THE ADVANCES IN MANAGEMENT OF MECHANICAL OBSTRUCTION OF THE SMALL INTESTINE

TOM SHIRES, M.D., AND K. O. ADWAN, M.D.

Dallas, Texas

INTRODUCTION

Mechanical obstruction of the small bowel is one of the most common problems seen by surgeons today. The over-all mortality associated with mechanical small intestinal obstruction in most reported series is approximately 10 per cent. Many advances have been made recently in the understanding of the pathologic physiology involved with mechanical intestinal obstruction, and the purpose of this paper is to present a review of our experience in the management of these obstructions based on an attempt to correct the underlying physiologic disturbances which occur in response to this illness.

It is obvious in a study of patients with this disease that the majority of physiologic derangements which occur are in the preoperative period. Understanding and correction of these derangements would seem to be the most important factors in attempting to lower the mortality rate. It is also true, however, that there have been advances in the operative management of mechanical intestinal obstruction as exemplified by the statement of Seabrook and Wilson[11] that the days of simple freeing of adhesions should be long past in modern surgery. This is also true in the operative anesthetic management of such patients as have been pointed out by Dodd.[2] Similarly, the postoperative and supportive care of patients suffering from this illness will have great bearing on the ultimate outcome.[1] Consequently, the management of the problem will be presented from the standpoint of preoperative, operative and postoperative care with illustrative case reports and ultimate results.

MANAGEMENT

The Preoperative Diagnosis and Management

Diagnosis. Signs of mechanical obstruction of the small intestines are legion until the onset of decompensational ileus intervenes. In general these signs include intestinal colic, hyperperistalsis, vomiting, obstipation and abdominal distention. In our experience the most reliable diagnostic criterion is elicited by auscultation of the the abdomen and hearing high pitched peristaltic sounds simultaneous with the patient's complaint of colicky pain.

The progression of mechanical obstruction to the point of decompensational ileus is usually heralded by the cessation of intestinal colic and hyperperistalsis and a change in the characteristics of vomiting from active regurgitation of fluid to overflow vomiting.

The most important changes in the diagnostic pattern of mechanical intestinal obstruction during the period of preparation for surgery are those changes which occur incident to mechanical interference with the blood supply to any segment of bowel. The signs we use[5] to determine the onset of interference with blood supply are as follows: (1) There is a change in the pain pattern from one of intermittent cramping pain to a continuous pain or the superimposition of a continuous pain between cramping. (2) Abdominal tenderness is usually absent between cramps in the absence of interference with the blood supply but changes so that tenderness exists between cramping pain episodes. This tenderness tends to be localized at its onset but spreads rapidly if generalized peritonitis develops. (3) Muscle spasm is usually present as voluntary spasm only during episodes of cramping pain, then when there is interference with blood supply, the patient develops involuntary abdominal muscle spasm. (4) In approximately one-half of those who develop interference of the blood supply there will appear a palpable abdominal mass in the area of the ischemic bowel. This represents a loop of bowel which has edema within the walls of the bowel and inside the lumen. (5) Shortly after the occlusion of blood supply there will develop signs of generalized peritonitis and tissue damage, including fever, tachycardia and leukocytosis, progressing to leukopenia.

From the Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

Physiologic derangements. The physiologic consequences of mechanical intestinal obstruction, even in the absence of interference of blood supply of the bowel, include[5]: (1) Respiratory exchange becomes progressively limited as abdominal distention progresses and asphyxia develops. (2) The pulse rate increases and hypotension occurs. These changes may be produced reflexly by distention of small segments of intestine, for example, closed loop obstruction or rapid distention of the stomach prior to, or in the absence of, any significant changes of the extracellular fluid volume. (3) Because absorption is remarkably reduced by a relatively small amount of distention, extracellular fluid rapidly collects within the lumen of the intestines. This fluid which is derived principally from the plasma represents an intravascular fluid loss into the bowel. In addition to the loss of fluid into the bowel lumen, fluid may be lost by vomiting. There is further loss of extracellular fluid and some sequestration of red blood cells into the wall of the hyperemic obstructed bowel.

In addition to the extracellular fluid volume deficit which inevitably occurs, there may also be ionic compositional disturbances, the nature of which depends upon the site and duration of the obstruction. These may include excesses or deficits of base bicarbonate, chloride, potassium, calcium and excesses of organic acid anions. The total concentration of electrolytes may be altered depending upon the site, duration of obstruction and, in addition, the amount of water ingested by the individual during the development of obstruction.

1. The starvation which inevitably occurs in dealing with longstanding or incomplete obstructions may become a major problem in physiologic replenishment.

2. The end result of a longstanding ileus is the development of gangrene of the bowel wall with leakage of bacteria into the peritoneal cavity. Necrosis occurs in the absence of major vessel obstruction if the distention is severe or of long duration. This will ultimately lead to generalized peritonitis.

It is obvious from the physiologic consequences that if all patients with mechanical intestinal obstruction are operated upon as soon as the diagnosis is made, the operative mortality will, and has been shown to be, in the neighborhood of 50 per cent.[5] Consequently, a reasonable delay in operative intervention should include time for (1) correction of the anoxia produced by respiratory restriction—massive distention of intestine encroaches upon the chest cage by elevation of the diaphragm and induces a shift in the respiratory position of the chest to one of maximum inspiration at all times; (2) replenishment of the diminished circulating and interstitial fluid volume; (3) correction of compositional and concentrational alterations in the extracellular fluid; and (4) improvement in the nutritional state of the individual, at least by repleting glucose deficiency.

Optimum time for surgery. If there are signs of interference with the blood supply to the bowel as with torsion, volvulus or thrombosis, immediate celiotomy should be performed if death of the patient is to be averted. In the absence of interference with blood supply certain considerations must be given to correcting the physiologic derangements. (1) Whereas intestinal intubation is considered because the preponderance of the gas within the bowel in all forms of ileus has been shown[13] to have entered through the esophagus, the use of nasogastric suction under these circumstances is mandatory. The short tube (Levin tube), in many instances of high mechanical obstruction, alone will suffice for a decompressive measure. However, if distention is massive or obstruction low in the small intestine then a long tube such as a Cantor tube or Miller-Abbott tube must be employed. No more than 4 to 6 hours should be spent in passing the tube beyond the pylorus by positioning the patient on his right side; after this time the tube should be passed into the small intestine under fluoroscopic control. Since gastric dilation will occur proximal to the balloon on a long tube, the concomitant use of a short tube in the stomach is advisable. Consequently, one or both tubes are needed to relieve the respiratory, cardiovascular, and extracellular fluid volume derangements incident to massive distention of the stomach and gut. (2) The signs of a peripheral blood volume deficiency which should be treated are best ascertained clinically. The best signs of blood volume depletion include (a) history of weakness, orthostatic vertigo and syncope, (b) the physical examination, which will reveal sleepiness, apathy, slow response to questioning and loss of interest in surroundings, progressing to stupor; tachycardia, orthostatic hypotension, slow filling of superficial veins progressing to recumbent hypotension, cold ex-

tremities and hypovolemic shock; or if the volume depletion has been relatively slow there will also be shrinking and longitudinal wrinkling of the tongue, diminished skin turgor and sunken and soft eye balls. In addition body temperature will be below normal if the ambient temperature is below 90°F. and if infection is not present. There may be no chemical evidence of abnormality in electrolyte concentration in the blood or the urine even with severe diminution in blood volume incident to extracellular fluid losses. Surgery should be postponed until fluid and electrolyte therapy have corrected the extracellular fluid volume deficit. (3) The changes in the composition and concentration of electrolytes is best ascertained by a chemical analysis of the serum including serum sodium, potassium chloride and and carbon dioxide. Appropriate therapy can then be directed at correcting such derangements. The osmolar concentration is reflected by the serum sodium and may be reduced as a result of the individual's drinking large volumes of water during the development of intestinal obstruction. Changes in the compostion of the electrolyte pattern of the blood may be affected by the location of the obstruction because in high obstructions the loss of relatively more acid may produce alkalosis, whereas if the obstruction is low in the ileum or the obstruction is chronic, there will develop a starvation ketosis with the production of acidosis. (4) The nutritional state of the individual preoperatively can usually be improved by the infusion of carbohydrate and vitamins. The administration of protein or fat parenterally in the short preoperative period, at the present time has more disadvantages than advantages.

The Operative Management

Anesthesia. The management of anethesia in intestinal obstruction with cognizance of the alterations in physiology were summarized in a report from this institution by Dodd[2]: (1) The importance of a Levin tube is stressed to prevent regurgitation of gastric contents into the oropharynx and aspiration into the lungs during anesthesia. This is particularly important in the presence of a long tube lying in the intestine since large amounts of fluid may pool in the stomach before or during the operative procedure. (2) Preoperative anesthetic medication which usually contains a respiratory depressant should be lighter than usual in order to avoid exaggeration of the ventilatory insufficiency caused by distention of gut. (3) Local anesthesia using novocaine and/or regional blocks supplemented by nitrous oxide is acceptable anesthesia in experienced hands and in selected patients such as the aged individual who has relatively poor pain appreciation. However, if the distention is massive or the individual is young, usually this type of anesthesia is not satisfactory. (4) Spinal anesthesia is contraindicated in the presence of unrelieved distention of the intestine for the wall of the gut may rupture during the smooth muscle contraction that follows spinal anesthesia. In order to be effective for abdominal incision, spinal anesthesia must be so high it will paralyze the intercostal muscles which may reduce tidal air to nearly zero since the diaphragm is already high and fixed by the intestinal distention. Hypotension is likely to ensue from spinal anesthesia as a result of sympathetic paralysis with a diminished blood volume which most such patients will have. The inadequate coronary flow that may attend the hypotension has been reported to cause cardiac arrest in many instances. (5) Pentothal anesthesia alone is contraindicated because of the profound respiratory depression. When used with a muscle relaxant, the airway may be flooded with stomach contents as a result of esophageal sphincter relaxation while the intraabdominal pressure remains high. (6) A preoperative preparation of approximately 30 min. of breathing pure oxygen on the anesthetic machine, virtually to denitrogenate the patient will often give an adequate blood-oxygen saturation reserve so that the individual may be more safely intubated even though a short period of apnea is produced. Previous denitrogenation may protect against a subsequent episode of anoxia which without denitrogenation may be enough to cause cardiac arrest or even respiratory failure. (7) When possible it is preferable to position the patient on the table with the feet slightly inclined downward so that the distended abdominal viscera are drawn away from the diaphragm, thereby rendering it somewhat less restricted in excursion. (8) Endotracheal intubation is preferable in patients with severe abdominal distention as respiration can be much more adequately assisted during the anesthetic episode. Cyclopropane and/or ether are satisfactory anesthetic agents if the other precautions previously mentioned have been observed.

Fluid therapy during the operative period. The type and amount of fluid given during the operative period will depend in part upon the completeness of preoperative correction of deficit incurred prior to the operative period. If the preoperative preparation has been adequate, the demand for fluids during the operative period will depend upon the amount of manipulative trauma to the bowel, the presence of peritonitis, the duration of the procedure, the rate of weeping from serosal surfaces and the rate of bleeding. The administration of a balanced salt solution, such as lactated Ringer's, is distinctly needed to replace the saltwater losses inevitably incurred during the operative period. At the present time, the volume of saltwater loss has been estimated grossly. If no plication or extensive lysis of adhesions or bowel resection needs to be done, 1000 to 1500 ml. of salt solution are sufficient. The requirement for 5 per cent glucose in water during surgery will be no more than that required to replace insensible loss of water, and this loss is not appreciably altered by the surgical procedure itself. Blood replacement in most operations for mechanical intestinal obstruction is entirely unnecessary since the internal losses of fluid into the lumen and wall of the bowel and the peritoneum, as well as the external losses by vomiting or suction, are predominantly extracellular fluids which can be replaced as lactated Ringer's fluid almost exactly. The red blood cell loss by sequestration may require preoperative or postoperative replacement in some instances if the obstruction is severe or longstanding and if the hematocrit falls below normal while evidence of low blood volume exists.

Enterotomy. Aseptic decompression through a pursestring suture in a normal bowel located proximal to the obstruction is routinely done where the distention has not been relieved prior to surgery. This aseptic decompression can be done without difficulty with a regular abdominal suction tip, with the guard in place, and obviates many of the consequences of obstruction which may occur even in the postoperative period. Fluid and air can be aspirated from the proximal and distal small bowel without difficulty. If small bowel resection is done at the time of the operation, then the proximal and distal loops can be aspirated just prior to reanastomosis. We believe that this procedure of aseptic decompression of the bowel adds materially to the postoperative recovery of this illness. We have never found it necessary to use permanent enterostomy in mechanical intestinal obstruction of the small bowel, because the fluid losses and possible consequences of fistula which ensue are far more hazardous than the gains to be made. The problem of decompression can be handled by aseptic decompression at the time of surgery followed by the placement of a long tube into the small intestine under direct vision at the time of surgery. We have never seen any complications from the use of this maneuver and believe it adds materially in the ultimate recovery.

Plication of the small intestine. As pointed out by Perry and associates,[9] adhesions have become the most common cause of small intestinal obstruction today. Until approximately 10 to 15 years ago external hernias were responsible for one-half of the obstructions of the small intestines and were the most common single cause; however, today probably in view of the fact that there is an increasing number of abdominal operations being done and possibly in addition the fact that more external hernias are repaired in infancy, adhesions from all kinds of surgery have become the most common cause of mechanical intestinal obstruction. Postoperative adhesions are the most common of all, constituting approximately 80 per cent of all adhesions. Inflammatory adhesions are next and probably cause around 15 per cent of the adhesions, with congenital bands composing a relativey minor percentage of all adhesions.[9]

In view of this fact, many people have searched for years for the cause of operative adhesions, and to date little has been gained in regard to prevention other than the general surgical principals of using absorbable powder, gentle handling of tissues and the removal of raw surfaces in the peritoneal cavity. Subsequently, Noble[9] has made the most remarkable advance in the handling of mechanical intestinal obstruction due to adhesions. The Noble plication procedure in some variation is now used almost entirely to prevent reobstruction by adhesion formation once this etiologic factor has caused mechanical intestinal obstruction. Noble[6] has now reported on 34 years' experience with the plication procedure in over 1300 patients in addition to many other reports, (10, 12) so that this procedure is time honored and very effective when properly used. The present day principles of utilizing the plication procedure as advocated by Noble[7] and others include: (1) The entire small bowel does not need to be pli-

cated in most instances. (2) The only areas of small bowel that need to be plicated are those where serosal denudation has occurred. No denuded serosa should be left exposed at the time of closing the abdomen following any intestinal obstruction if at all preventable. (3) Noble advocates continuous plication of loops, approximately 8 to 10 in. in length, in juxtaposition. He utilizes a continuous 00 or 000 chromic catgut suture beginning at the base of the mesentery of the anticipated plicated two loops and continuous suture from the base of the mesentery up to the two loops and then joining the midantimesenteric borders of one loop to the contiguous loop. In this manner serosal approximation can be made, and the previous area of adhesions or serosal denudation can be inverted so that they are no longer exposed for further adherence to areas of peritoneal interruption where previous adhesions have formed. Many surgeons are using interrupted permanent sutures such as cotton and silk for plication of the adjacent loops; however, Noble has reoperated upon some such patients and found that the "spot welding technique" does not hold the bowel in juxtaposition so well as or so permanently as continuous suturing by his technique.

Suffice it to say that the plication procedure is a valuable and worthwhile adjunct to surgery and should obviate most of the "intestinal cripples" which have been more and more frequent in recent years from recurrent bouts of mechanical obstruction due to adhesions. This has certainly been borne out in our own experience as reported in the present paper.

In addition to the areas of plication for denuded serosa mentioned before, there are certain segments of bowel which in the process of freeing are denuded of serosa circumferentially. These areas do not lend themselves well to Noble's plication procedure and in such instances primary small intestinal resection with end-to-end anastomosis is employed. This is done in preference to the older method of side-to-side entero-enterostomy to "short-circuit" areas of inextricable adhesions because many times these areas which are bypassed will subsequently develop a closed loop with perforation of the bowel.

Postoperative. Probably the most important feature of the postoperative care of patients with mechanical intestinal obstruction is the management of fluid and electrolytes. As has been pointed out,[4] any small excess of extracellular fluid volume (salt and water) will interfere with the healing of any bowel anastomosis or areas of suturing such as plicated intestine. It has further been pointed out by Moyer[3] that there is a relative renal intolerance to handle salt loads in the immediate postoperative period. Consequently, the fluid therapy in the postoperative periods should be carefully guided.

Water needs as water without electrolytes can be calculated simply by replacing urine loss for the previous day with 5 per cent glucose in water, and in addition insensible loss from skin and lungs can be generally estimated at 800 to 1000 cc. of 5 per cent glucose in water daily in the absence of any evidence of a hypermetabolic state. Saltwater needs in the postoperative period are virtually zero with the exception of measurable salt losses such as through gastroduodenal suction or long intestinal tube suction. Other measurable losses either can be measured or fairly accurately estimated; these would include fistula drainage, diarrhea, and sweating. The fluid lost should be replaced as a similar fluid, as, for example, most intestinal fluid losses can be replaced easily with lactated Ringer's solution. The routine use of salt containing solutions in the immediate postoperative period in the absence of measurable need or pre-existing deficit is to be condemned, particularly in view of the surgical procedures that must be done on the bowel at the time of the operation for intestinal obstruction.

2. The intestinal tube is used postoperatively. Usually a long tube has been threaded into the small intestine at the time of surgery, and this may be left in place until such time as the patient is freely passing gas and having normal bowel sounds postoperatively. This will average from one to four days as a rule. Levin tube suction is used similarly and when there is evidence of normal bowel function as evidenced by these signs, both tubes are removed simultaneously. As it has been stated previously, since most of the air enters the stomach and intestinal tract *via* the esophagus, it is felt that the so called "trial feeding" around any form of tube left in place, such as a Levin tube or a Miller-Abbott tube, is to be condemned; these tubes hold open the superior constrictor of the esophagus as well as the cardia and permit the easy ingress of air into the stomach. If these tubes are clamped off while feeding

occurs and air enters more easily around the tube, the development of gastric dilation or distention is quite common.

3. It has also been shown that prolonged obstruction of the small intestine apparently gives time for multiplication to the normal number of bacteria present in the small bowel. Since decompression and often times resection, handling and sewing of the bowel are unavoidable during surgery for intestinal obstruction it is felt that these patients usually should be placed on antibiotics for a short period of time. Since penicillin and Achromycin have been shown to be the most effective drugs against the usual organisms involved we ordinarily use a tetracycline compound either with or without penicillin depending upon the duration and severity of the obstruction.

CASE REPORTS

The following case reports illustrate principles described under management, including fluid therapy and plication.

Case 1. I. B. W., a 46-year-old colored woman, was admitted to the hospital on April 6, 1957. The patient gave a history of having had a complete bilateral salpingo-ophorectomy and total hysterectomy 3 weeks prior to admission, on the gynecologic service, for severe persistent metrorrhagia and at that time was admitted with a hemoglobin of 2 gm. On that admission her anemia was treated with intramuscular iron, and the hemoglobin rose to 11 gm. in 10 days at which time she had her surgery. Postoperatively the patient did well and was discharged one week after surgery. In the 3-week interval prior to readmission she had done well. Two days prior to admission she developed cramping upper abdominal pain followed in 6 hr. by vomiting and in 12 hr. by progressive distention of the abdomen. On her admission to the hospital she was seen to exhibit signs of extracellular fluid volume deficit manifested by apathy, weakness, collapse and empty veins, orthostatic hypotension and tachycardia of 110 per min. Physical examination revealed a markedly distended abdomen, cramping pain coincident with high pitched rushing bowel sounds and marked increase in tympany over the entire abdomen. There was no tenderness between cramps and she was relatively pain free between episodes of cramping pain. No masses were felt, temperature was 100°F., white blood cell count was 12,000 with no left shift, carbon dioxide content was 27 mEq./L., chloride was 102 mEq./L., urea nitrogen was 15 mg. per cent. Scout film of the abdomen showed many dilated loops of mechanically obstructed small intestines. There was no gas in the colon whatsoever. Hemoglobin was 11 gm. per cent.

The patient was given 2 L. of lactated Ringer's solution intravenously, a Levin tube was put into the stomach and an unsuccessful attempt was made to pass a long intestinal tube. The tube was removed and approximately 6 hr. later the patient was operated upon. Operative findings were extensive adhesions to the previous site of pelvic surgery, producing mechanical intestinal obstruction. After the adhesions were freed, several loops of small bowel were denuded of serosa, and a decompressive aseptic enterotomy was done with removal of approximately 500 cc. of extracellular fluid within the bowel. These loops were then plicated, according to the method of Noble, in 8-in. segments from the ileocecal valve up to mid-jejunum. The remainder of the bowel was normal. During the surgical procedure the patient received 2000 cc. of 5 per cent glucose in lactated Ringer's solution and no blood. Postoperatively she was given 1500 cc. of 5 per cent glucose in water during the remainder of the day. The following day the patient had minimal bowel sounds, no cramping and remarkably less distention. The patient was given 2000 cc. of 5 per cent glucose in water during the day plus an additional 1000 cc. of lactated Ringer's solution intravenously to replace measured gastrointestinal suction loss. This same fluid therapy was continued for 3 days, at which time she developed normal bowel sounds and was passing gas; the Levin tube was removed, she began to eat well, was ambulatory and discharged from the hospital on the seventh postoperative day.

This patient represents acute mechanical intestinal obstruction due to postoperative adhesions and illustrates the principles of preoperative extracellular fluid volume replacement, 2 L. of lactated Ringer's in this instance; the operative replacement of extracellular fluid which was lost during surgery, again 2 L. Also, the principle of aseptic decompression and plication of denuded serosa is illustrated.

Case 2. J. B. J., a 41-year-old colored man, was admitted to the hospital on August 7, 1957, with a history of having sustained a gunshot wound of the right lower quadrant of the abdomen followed by laparotomy in 1940. Since that time, he had been asymptomatic in the ensuing 17 years until one day prior to admission, at which time he noted a colicky periumbilical pain that occurred every 3 to 5 min. and was followed by persistent and protracted vomiting. Because of persistence of pain and vomiting, he came to the hospital, at which time he appeared acutely ill. His veins filled poorly; his blood pressure was 120/80; pulse

was 100; hemoglobin was 14.8 gm. per cent; white blood count was 12,000 with a normal differential. Examination of the abdomen revealed generalized abdominal distention without tenderness or muscle spasm. Auscultation revealed high pitched rushes coincident with pain every 4 min. X-ray of the abdomen revealed a characteristic pattern of mechanical small bowel obstruction, apparently in the ileum, with no gas present in the colon. A Cantor tube was inserted, as was a Levin tube, and the patient was started on lactated Ringer's solution intravenously. Twelve hours after admission the veins filled well, pulse was 80, temperature which had been 100°F. on admission was now 101°F., white blood count had risen to 18,000, the patient's cramping pains increased in severity, and in addition there was tenderness in the abdomen between cramps. No mass was palpable but a moderate amount of involuntary muscle spasm was present over the right side of the abdomen. It was decided at this time that interference of the blood supply of the intestine had occurred and laparotomy was planned.

At operation there was seen to be marked fibrous adhesions in the right lower quadrant at the site of the previous gunshot wound, and there had occurred a volvulus involving a 3-ft. segment of ileum around this fibrous band extending from the base of the mesentery to the anterior abdominal wall. The volvulus was reduced, the bowel was seen to be viable, adhesions were then separated, and there were seen to be two other areas of dense adhesions between the intestinal wall and the anterior abdominal wall in the right lower quadrant. These were freed and in all areas where the serosa was denuded the loops of small intestines were plicated. During surgery the patient received 1000 cc. of 5 per cent glucose in lactated Ringer's solution and an aseptic decompression of the small intestine was done in the midjejunum just above the plicated area. Postoperatively the patient was given 2000 cc. of 5 per cent glucose in water, followed the next day by 2000 cc. of 5 per cent glucose in water and 1 L. of lactated Ringer's which was to replace a measured 1 L. loss through the Cantor tube. On the third postoperative day bowel sounds were normal, gas was passed and the tubes were removed. The patient began to eat, was ambulated easily and was discharged on the fifth postoperative day.

This is an illustration of an acute mechanical intestinal obstruction again due to adhesions associated with the usual extracellular fluid volume deficit. There were no concentration or compositional disturbances apparently as a result of the fact that the obstruction was low in the small intestines. During the period of preparation for an attempted decompression and fluid replacement for surgery this patient developed minimal early but definite signs of mechanical interference with the blood supply of the intestines; consequently, laparotomy was done immediately thereafter. It was found that the volvulus which had occurred did produce temporary interference in blood supply of the involved small bowel but the bowel was still viable. Again lactated Ringer's solution was given as preoperative replacement and during the surgical procedure. Aseptic decompression was used for relief of distention at the time of the operation, and plication according to the method of Noble was again employed to prevent recurrence of the mechanical intestinal obstruction.

Case 3. L. M. S., a 42-year-old white married woman, was admitted to the hospital on March 5, 1955. This patient had an abdominal hysterectomy 9 years prior to this admission, and in the ensuing period she had had 8 exploratory laparotomies for freeing adhesions which were causing mechanical intestinal obstruction. No definitive procedure had been performed at any operation. On three occasions, historically, the patient gave evidence of having had mechanical interference of the blood supply with loops of bowel. On this admission the patient began to have cramping periumbilical abdominal pain and vomited 24 hr. prior to admission, with coincident cessation of passage of flatus. Physical examination at the time of admission revealed an acutely ill woman who was quite apathetic and weak, and showed no interest in her surroundings whatsoever. Her peripheral veins filled quite slowly, she had pulse of 110 per min., blood pressure was 120/80 and when she was placed in a sitting position blood pressure fell to 100/60. Her eyeballs were soft and sunken, and there was already some loss of tissue elasticity. Examination of the abdomen revealed marked distention of the entire abdomen with high pitched peristaltic rushes coincident with the cramping pain. There was definite tenderness between cramps and a moderate amount of involuntary spasm over the entire abdomen. White blood count was 15,000 with a moderate left shift, temperature was 101°F. Nasal gastric suction was instituted and the patient was given 2000 cc. of 5 per cent glucose in lactated Ringer's solution. X-ray examination confirmed the diagnosis of mechanical small intestinal obstruction. Laparotomy was performed 6 hr. after admission; there were multiple dense fibrous adhesions to all previous laparotomy wounds throughout the entire abdominal cavity and virtually the entire small bowel was involved. There was one area at the site of this present obstruction which had undergone a volvulus of

approximately 8 in. in length around the adhesion, and there was definite early interference of the blood supply to the involved loop. The volvulus was reduced and the adhesions were freed. Following this the adhesions to the small bowel were freed from the ligament of Treitz to the ileocecal valve. There were two areas in midileum which were so intimately bound to the adhesions in the pelvis that serosal denudation was effected circumferentially involving the entire circumference of the bowel for a period of approximately 2 ft. Because of this it was thought that plication could not invert the denuded serosa, and this area of the bowel was resected with an end-to-end anastomosis being done. Following this a plication of the entire small bowel from the ileocecal valve to the ligament of Treitz was done, using approximately 8-in. loops. During surgery the patient was given 2500 cc. of lactated Ringer's solution, and aseptic decompression was done through the resected site prior to the anastomosis. On the day following surgery the patient received 2000 cc. of 5 per cent glucose in water intravenously and an additional 1000 cc. of lactated Ringer's to replace gastrointestinal suction fluid lost. The following day she received 2 L. of 5 per cent glucose in water intravenously plus 500 cc. of lactated Ringer's solution for replacement of salt water loss *via* nasogastric suction and on the following day she had good active bowel sounds and was passing gas. The tubes were removed; she was allowed to drink and eat, and she was discharged from the hospital on the sixth postoperative day asymptomatic. She has remained well to date.

This patient once again illustrates acute mechanical obstruction with the necessary preoperative and operative fluid replacement. In this instance there were such severe adhesions producing serosal denudation to free the adhesions that a small segment of the small bowel had to be resected in order to prevent subsequent adhesion formations.

RESULTS

The case reports are used to illustrate the management of the derangements in physiologic principles and advances which have occurred in the management of patients with mechanical intestinal obstruction. Utilizing the principles outlined, we have managed as private or service cases 64 patients with mechanical small intestinal obstruction from all causes in the past two years. Of these, 10 have required extensive plication of the small intestine caused by serosal denudation in order to prevent recurrence of the obstruction. Four of this group of patients have had viability of bowel impaired as a result of the intestinal obstruction requiring resection. In addition there have been 24 private patients managed in the past five years requiring plication of varying amounts of small bowel. There have been no recurrences requiring surgery in any of this group. The mortality has been zero for the entire group.

SUMMARY

1. Since mechanical obstruction of the small intestine is one of the most common problems seen by the surgeon today, it was thought worthwhile to review the advances in the management of mechanical small bowel obstruction.

2. The salient preoperative, operative and postoperative features of diagnosis and physiologic derangements attendant upon the illness of small intestinal obstruction have been reviewed.

3. Advances in the management of preoperative, operative and postoperative periods of mechanical intestinal obstruction have been outlined and reviewed.

4. Results based upon management utilizing the physiologic principles reviewed are presented.

REFERENCES

1. Cole, W. H.: Operability in the young and aged (Roswell Park lecture). Ann. Surg., *138:* 145, 1953.
2. Dodd, R. B.: Problem in anesthesia for intestinal obstruction. South. M. J., *45:* 805, 1952.
3. Moyer, C. A.: Acute temporary changes in renal function associated with major surgical procedures. Surgery, *27:* 198, 1950.
4. Moyer, Carl A.: *Fluid Balance, A Clinical Manual*. Chicago, Yearbook Publishers, Inc., 1952.
5. Moyer, C. A., Harrison, T. R.: *Principles of Internal Medicine*, p. 40–53. Philadelphia, Blakiston Company, 1950.
6. Noble, T. B.: Intestinal suturing and plication. J. Internat. Coll. Surgeons, *22:* 174, 1954.
7. Noble, T. B.: Intussusception and plication. Am. J. Surg., *94:* 139, 1957.
8. Noble, T. B., Jr.: Plication of small intestine as prophylaxis against adhesions. Am. J. Surg., *35:* 41, 1937.
9. Perry, J. F., Jr., Smith, G. A., and Yonehiro, E. G.: Intestinal obstruction caused by adhesions. Ann. Surg., *142:* 810, 1955.
10. Poth, E. J., Lewis, S. R., and Wolma, F. J.: Treatment of recurring intestinal obstruction by the plication procedure. Am. Surgeon, *19:* 24, 1953.
11. Seabrook, D. B., and Wilson, W. D.: Prevention and treatment of intestinal obstruction by use of the Noble procedure. Am. J. Surg. *88:* 186, 1954.
12. Stone, D.: A report on the Noble operation for the management of intestinal adhesion. Tr. South. S. A., *65:* 360, 1953.
13. Wagensteen, O. H.: *Intestinal Obstruction*. Springfield, Ill., Charles C Thomas, Publisher, pp. 19–20, 1945.

CLOSURE OF INTERATRIAL SECUNDUM DEFECTS: SIMPLIFIED BY UTILIZATION OF A PREVIOUSLY UNDESCRIBED ANATOMIC FEATURE

HUGH E. WILSON, M.D., R. H. CARDOZO, M.D., J. L. KEE, M.D., AND E. K. SIEBEL, M.D.

Dallas, Texas

A previously undescribed anatomic feature has aided in the closure of interatrial septal defects of the secundum type by a modification of the Søndergaard technique. This modification assures closure of the defect by allowing easy access to Søndergaard's tunnel with a blunt probe and avoids false passage into either atrium.

Since the pioneering efforts of Cohn[7] in 1947 and Murray[13] in 1948, a number of techniques for blind closure of atrial septal defects have evolved. Notable among these have been the atrioseptopexy of Bailey and associates[2] and the technique of Gross[10] used to great advantage by Watkins, Gross and associates[18] and by Pemberton, Kirklin, and Wood.[14]

In 1952 Søndergaard and Husfeldt demonstrated the practicability of dissecting the dorsal interatrial groove between the right pulmonary veins and the back of the vena cavae and right atrium. Then anchoring sutures in the septal edge were tied behind the cavae in the dissected dorsal interatrial groove, thus closing experimental septal defects. Bjork and Crafoord[4] modified this to include digital control. A finger, placed in the right atrium through the appendage, guided insertion of a large needle through the anterior edge of the septal defect and determined proper tension on the ligature.

In 1954 Søndergaard and coauthors[16] described the areolar tunnel between the layers of the interatrial septum at its base, above the interventricular septum. A *blunt probe* was passed through this tunnel to introduce a heavy suture. This was then tied in the dissected dorsal interatrial groove to close the defect[15] as in earlier techniques.

These techniques have been employed by others.[1, 5, 6, 8, 17] The failures which have occurred can be grouped as the result of (1) the ligature's "cutting through" (dorsally), (2) the ligature's being intra-atrial (not within the septal edge) and (3) incomplete closure of the defects. The importance of the latter has been well demonstrated by Kirklin.[11]

FIG. 1. Photograph of right posterior and inferior aspect of dog's heart filled with saline. Note the prominent "dimple" (arrow) at the junction of the inferior vena cava, the coronary sinus and the right and left atria. This landmark is not easily seen in a flaccid heart at autopsy.

One of the authors (H. E. W.) in earlier experiments on dog hearts noted that a "dimple"* is consistently present at the caudal end of the areolar tunnel described by Søndergaard. This can be quickly located at the junction of the inferior vena cava, the coronary sinus and the right atrium (fig. 1). Studies on human postmortem specimens and observation during cardiotomy for other lesions show the depression to be universally present though occasionally filled with fat and therefore not obvious. This dimple represents a precise anatomic landmark for passage of a

From the Division of Cardiac and Thoracic Surgery, Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

* DeWall, Warden, Lillehei and Varco mention a dimple that occurred on the back of dogs' hearts, marking the posterior commissure of the mitral valve. Apparently they did not realize its significance as an entry to Sondergaard's tunnel in dogs and human beings.[9]

blunt instrument into the areolar tunnel in contrast to the less exact anatomic landmark of "the root of the aorta" as described by Søndergaard.

Employing this technical modification and dissection of the interatrial groove as described by the original authors a series of interatrial septal defects in animals and in man were closed.

METHOD

Fourteen mongrel dogs weighing between 13 and 23 kg. were anesthetized with veterinary Nembutal and sustained on 100 per cent oxygen administered by a Halliburton respirator. A standard right lateral thoracotomy through the 5th intercostal space was performed and the pericardium opened anterior to the phrenic nerve. The cavae were isolated and encircled with umbilical tapes and the azygos vein divided. The dorsal interatrial groove was dissected, as described by Søndergaard, from the root of the aorta to the coronary sinus (fig. 2).

In earlier experiments, a Gross atrial well was attached to the right atrium and through it an atrial septal defect created. In the later procedures it was found possible, working directly through the atrial appendage, to create a defect which easily admitted an index finger. After a defect was created and oxygenated blood demon-

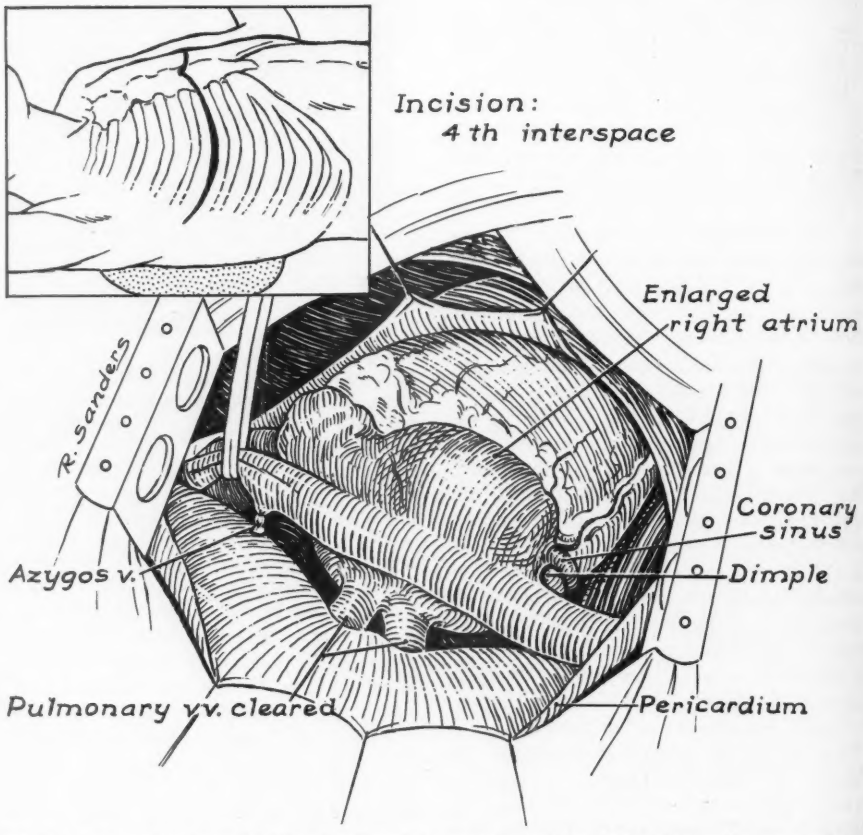

FIG. 2. A groove has been developed between the anterior surface of the right pulmonary veins and left atrium and the posterior aspect of the vena cava and right atrium as described by Søndergaard. The inset demonstrates the incision used in human cases. The 5th intercostal space incision is used, transecting the sternum, if an interatrial septal defect is the only lesion. A right 4th and left 3rd intercostal incision is utilized if other lesions are present.

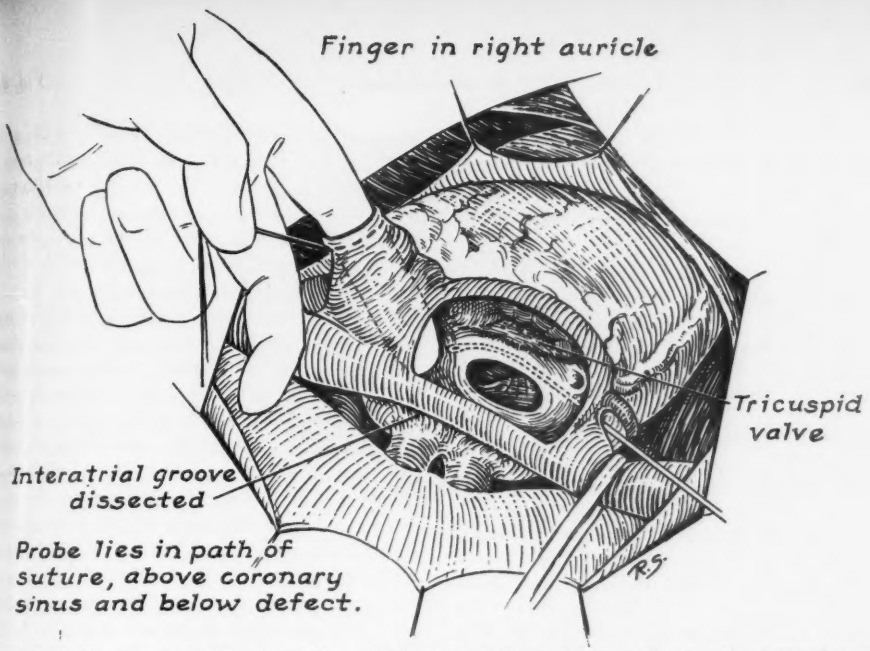
Finger in right auricle
Tricuspid valve
Interatrial groove dissected
Probe lies in path of suture, above coronary sinus and below defect.
R.S.

FIG. 3. A blunt probe is introduced through the "dimple" into the tunnel above the A-V valves to emerge at the base of the aorta behind the right coronary artery.

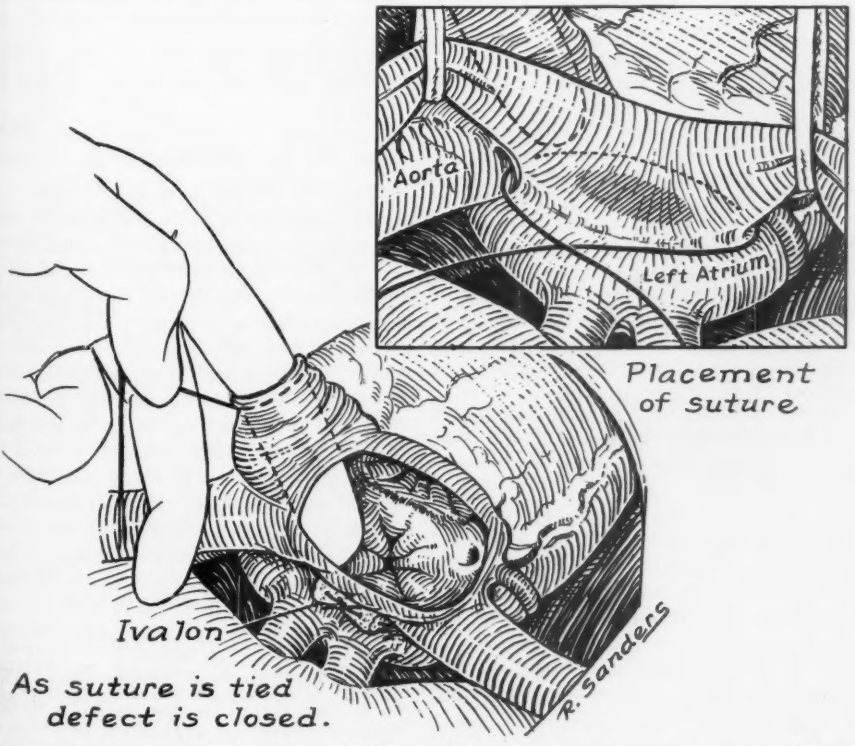

FIG. 4. Inset demonstrates that heavy silk ligature has been drawn through Søndergaard's tunnel and the ends passed under the venae cavae.

The ends of the silk ligature are threaded on Keith needles and passed through opposite ends of an oblong pledget of uncompressed Ivalon sponge. An assistant ties the suture in the dorsal groove so as to securely close the interatrial septal defect as determined by the intracardiac finger.

TABLE 1

*Summary of experimental procedures on dogs**

No.	Survival Time	Cause of Death	Postmortem Findings
	days		
1	42	Sacrificed	Well closed — ligature not visible
2	63	Sacrificed	Well closed — ligature not visible
3	5	Empyema	Suture cut through dorsal interatrial groove†
4	—	Operative death	Aortic tear — defect closed
5	30	Sacrificed	Well closed — ligature not visible
6	42	Sacrificed	Well closed — ligature not visible
7	91	Sacrificed	Well closed — ligature not visible
8	4	Empyema	Not completely closed (2 mm. orifice)
9	132	Sacrificed	Well closed — suture beneath endothelium but may have been originally exposed in right atrium
10	154	Sacrificed	Well closed — ligature not visible
11	100	Sacrificed	Well closed — ligature not visible
12‡	1	Hemorrhage	Well closed — ligature not visible

* Number of experiments, 12; operative deaths, 2; completely closed, 10; not completely closed, 1; suture cut through,† 1.

† A deliberate effort was made to determine if and where a 2-0 ligature would cut through if very tightly tied without an Ivalon pledget in the dorsal groove.

‡ Hole inadvertently cut in back of atrium with severe hemorrhage during creation of interatrial septal defect. Death postoperatively due to hypovolemia.

strated in the right atrium, a finger was placed through the right atrial appendage as a guide. The epicardium of the dimple was broken with a hemostat and then a blunt, malleable probe was passed through the base of the atrial septum to emerge to the right of the base of the aorta (fig. 3). A no. 4 silk ligature was then threaded into the probe and withdrawn through the tunnel. After the ligature ends were passed medial to the cavae, they were tied down over a pledget of Ivalon. The tightness was controlled by the intra-atrial finger (fig. 4). When the ligature had been tied and closure ascertained by palpation, the finger was removed and the auricular appendage amputated and oversewn.

Of the 14 dogs used in the experiments, 12 were subsequently examined at autopsy.* The results are shown in table 1. There were two operative deaths, one due to a tear in the aorta caused by a technical error. In this animal the defect was well closed by the ligature. The second operative death resulted from a hole in the dorsal aspect of the left atrium which occurred during the blind creation of an interatrial septal defect. The ligature was nevertheless passed and, although the animal later died of hypovolemia, the defect was demonstrated to be well closed. In 10 animals of which 8 survived more than 30 days, the defect was well closed (fig. 5). In one animal a 2-mm. defect remained, and in one animal a *deliberate effort* was made to cause the ligature to cut through the interatrial groove. It did so and was found in the lumen at autopsy 5 days after closure. In this case no. 2-0 silk was used instead of no. 4 and Ivalon was not placed under the ligature posteriorly.

DISCUSSION

The circumclusion technique for closure of interatrial septal defects has failed in the hands of various surgeons because of incomplete closure, exposed suture material in the chambers or the ligature's cutting through the atrium or septum. These failures are due to lack of strict adherence to the basic anatomic observations of Søndergaard regarding the normal areolar tunnel at the top of the ventricular septum (fig. 6). If a sharp needle is used to place the ligature in the septal edge, it is likely to result in incomplete closure or the ligature may tear out. When attempts are made to employ this technique in defects variously described as ostium primum defects, persistent atrioventricular canal or endocardial cushion defects, *in which the areolar tunnel by definition cannot exist*, failure is again invited and damage to the conduction system is likely.

* The two dogs not autopsied survived surgery with the defects presumably closed. One was used for another project and not returned; the other died of distemper and was inadvertently destroyed before autopsy.

FIG. 5. Heart from animal sacrificed 6 weeks after the closure of interatrial septal defect by circumclusion method. Arrow points to thin, smooth scar on the right atrial side of the interatrial septum. The left side has a similar appearance.

If the ligature does not lie completely within the tunnel due to false passage of the probe, failure is also likely.

Employment of the anatomic dimple as an entrance to this areolar tunnel facilitates optimum utilization of the anatomic features on which Søndergaard devised his circumclusion technique.

The described technique, like other closed techniques, is dependent for its successful use on the differential diagnosis of simple secundum defects from those pertaining to a persistent atrioventricular canal. Diagnostic acumen has been highly developed in centers employing closed techniques extensively[3, 12] and the errors in differentiation reduced to a minimum. The current practice in this clinic, when in doubt about the diagnosis, is to begin the procedure with the pump oxygenator prepared. If the diagnosis of a simple secundum defect is correct, closure is effected by the procedure described. If the defect is not amenable to this technique, the extracorporeal circuit is connected and an open heart procedure used. By this plan the risk of cardiopulmonary bypass and the risk of air embolism from air trapped in the left side during closure of the defect by open techniques is avoided whenever possible.

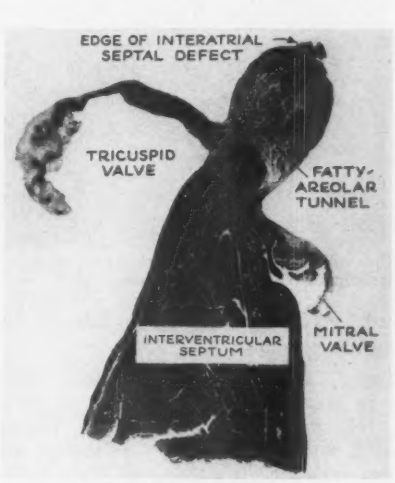

FIG. 6. Photomicrograph of the lower rim of interatrial septum and upper portion of interventricular septum from a human heart with an interatrial septal defect of the secundum type. The fatty areolar tunnel through which a blunt probe may be passed is easily seen.

CLINICAL CASES

The feasibility and effectiveness of the described method of closure was established by animal experimentation. The modified Sønder-

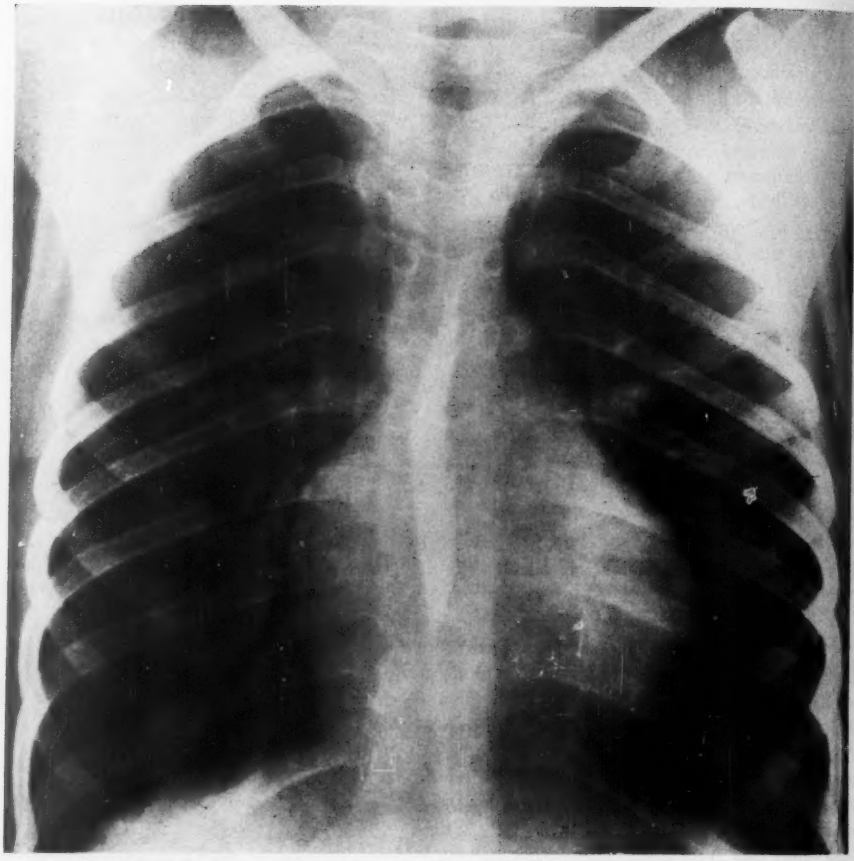

FIG. 7*A*. Preoperative chest x-ray, case 1. P-A projection showing poststenotic dilatation of the pulmonary artery and enlargement of the right atrium.

gaard technique was employed clinically. Three cases are presented.

Case 1. R. L. Y., a 10-year-old white boy, had known heart disease since the age of 3 years. In 1950 an angiocardiogram had been performed and the diagnosis of interatrial septal defect was made. Since the age of 3 there had been episodes of cyanosis on exertion followed by periods of unconsciousness. The last such episode, about 3 months prior to admission, left him unconscious for 10 or 20 min. The referring physician reported that he was in cardiac failure at that time.

In addition to marked physical limitation a diagnosis of mental retardation had been made by several physicians. For these reasons he was attending a special school. One eye had been removed at the age of 3 because of congenital glaucoma.

Physical examination revealed a thin, 48-lb. boy with cardiac rate of 80 and blood pressure of 100/70 in the arms and 130/80 in the legs. There was an ocular prosthesis on the left. Examination of the heart revealed a left precordial bulge and a palpable thrill along the left sternal margin. A grade III–IV harsh systolic murmur was heard along the left sternal border with maximum intensity in the 2nd and 3rd intercostal spaces. The pulmonic second sound was slightly diminished.

He was admitted to the hospital for further studies. X-rays (fig. 7) revealed right ventricular hypertrophy, a suggestion of poststenotic dilation of the pulmonary artery and reduced pulmonary vasculature. Electrocardiograms revealed pronounced right ventricular hypertrophy. Cardiac catheterization was performed and the data obtained is shown in table 2.

FIG. 7*B*. Preoperative chest x-ray, case 1. Lateral projection. Note marked right ventricular hypertrophy.

Hematologic studies were within normal limits. He was digitalized, placed on a low sodium diet and given mercurial diuretics with a loss of over 3 lb.

On May 28, 1957, under endotracheal general anesthesia the patient was positioned in the dorsal decubitus position with the right side elevated 30°. A bilateral thoracotomy was made in the right 5th and left 3rd intercostal spaces, transecting the sternum. The pericardium was opened and marsupialized. The pulmonary artery, aorta and venae cavae were isolated by sharp dissection. Digital exploration through the right atrial appendage revealed a large (approximately 3 cm. in diameter) interatrial septal defect of the secundum type. There was no ridge to the defect superiorly but a small ridge was palpated inferiorly and posteriorly and above the atrioventricular valves. Exploration of the ventricle by palpation revealed no evidence of an interventricular septal defect.

TABLE 2

Results of cardiac catheterization

Area Catheterized	Oxygen Content by Volume	Pressures
	%	*mm. Hg*
Left innominate vein	6.55	
Superior vena cava	5.15	
Right atrium	9.60	
	8.85	6 (mean)
Right ventricle	11.15	52/4
Pulmonary artery	11.95	27/12.5
	12.40	
Femoral artery	13.30 (88%)	

A stenotic pulmonic valve was palpated with the intracardiac finger. There was no evidence of infundibular stenosis.

Following completion of the exploration, the

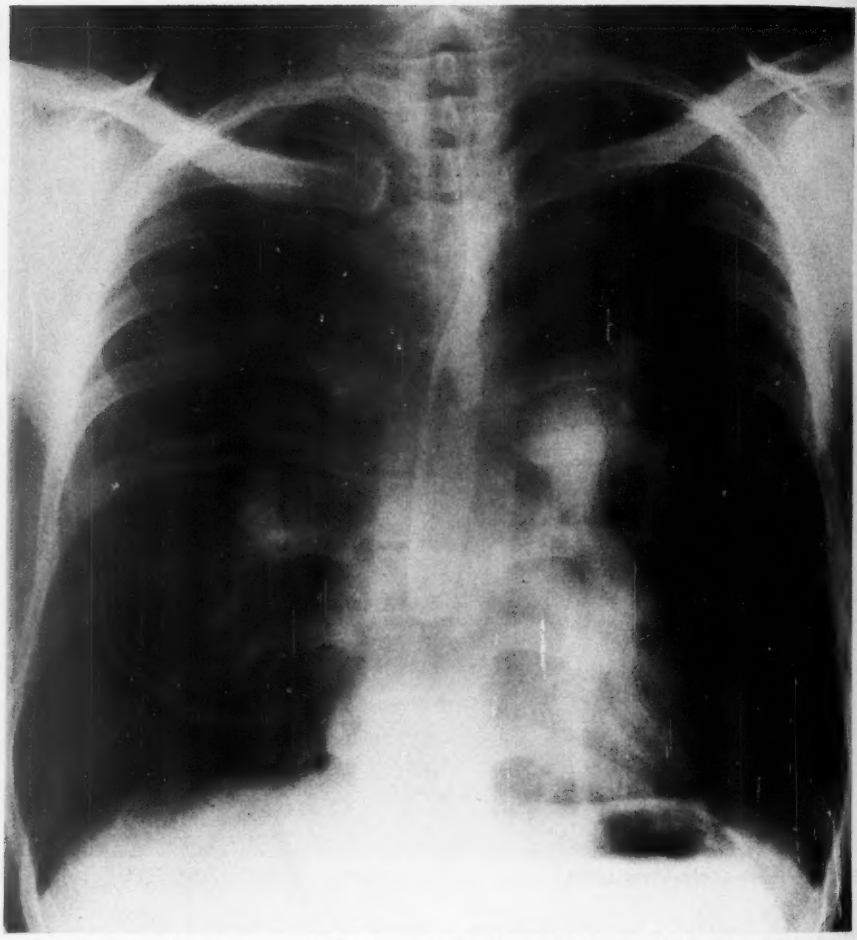

FIG. 8*A*. Preoperative x-ray, case 2. P-A projection demonstrating marked enlargement of the pulmonary artery and of its branches in the hilar areas.

dorsal interatrial groove of Søndergaard was developed and the interatrial septal defect closed by the technique described in this report. Palpation and blood samples taken after completion of the defect indicated its complete closure. Cannulae were placed into the superior and inferior venae cavae through the right atrium and into the iliac artery *via* the right femoral artery. The cavae were occluded about the cannulae as total cardiopulmonary bypass was instituted with the use of a modified DeWall-Lillehei oxygenator run at a flow sufficient to maintain the direct arterial mean pressure at or above that measured prior to thoracotomy. The pulmonary artery was cross-clamped, opened and valvular pulmonic stenosis relieved by incising in three rudimentary commissures out to the annulus. The absence of an interventricular septal defect was again confirmed. The heart was filled with warm Ringer's solution and the pulmonary artery closed. Surgery was completed in the usual fashion.

The patient's postoperative course was uneventful. He was discharged from the hospital on the 14th postoperative day. Except for episodes of cardiac failure with extreme exertion during the first postoperative month (running races with other boys of his age) his postoperative course was uneventful. There is no evidence of a pulmonary diastolic murmur. The heart has decreased in size and the patient's exercise tolerance increased to

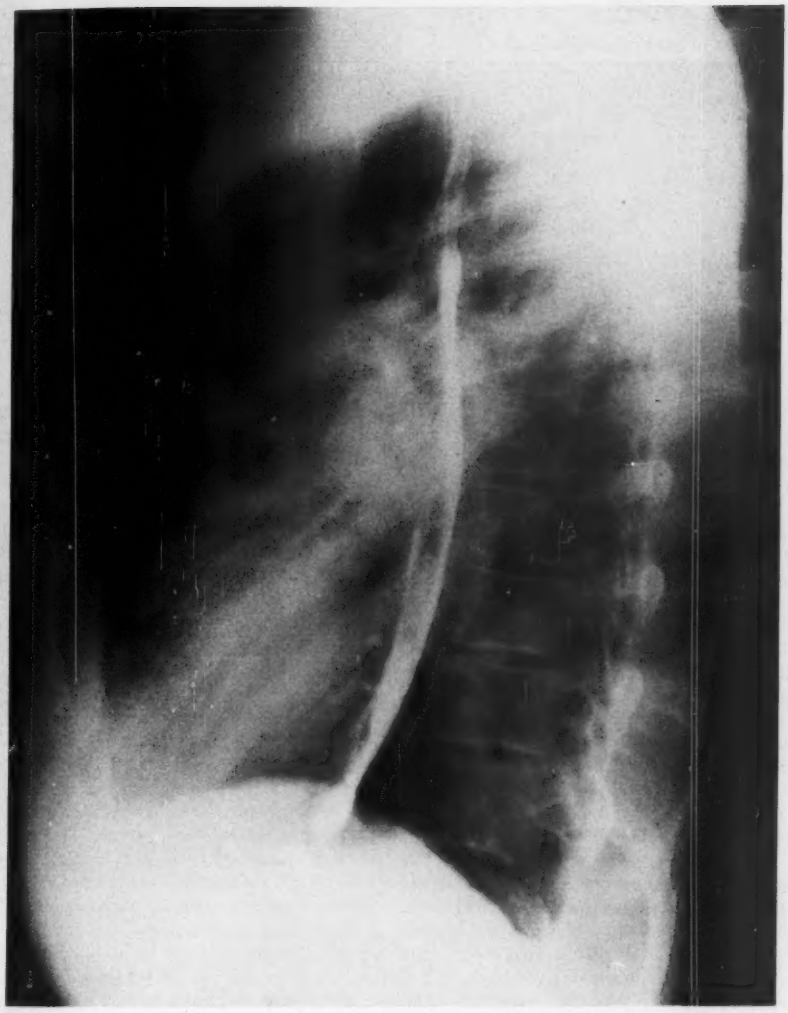

FIG. 8*B*. Preoperative x-ray, case 2. The lateral projection demonstrates enlargement of the right ventricle and prominent pulmonary artery shadows.

normal. Six months following surgery, he had grown taller and had gained 12 lb. There was no evidence of cardiac failure. The electrocardiogram and x-rays have approached normal. Repeat catheterization has not as yet been performed.

Case 2. R. S., a 39-year-old man, was admitted to the hospital complaining of shortness of breath which was increasing in severity over the past 6 months.

Past history revealed that a murmur had been discovered at the Naval Academy in 1939 but that he had never had any shortness of breath or cyanosis, in spite of strenuous physical activity, until his present illness. Seven months prior to admission he had had a "chest cold" which had been treated with penicillin and streptomycin. Since that time he had had three recurrences with an irritating nonproductive cough. Dyspnea had increased to the point where he was unable to do anything at all strenuous without stopping to catch his breath.

Physical examination was essentially negative except for his chest. The lungs were clear to auscultation and percussion. The heart showed

TABLE 3

Results of cardiac catheterization

Areas Catheterized	Oxygen Content by Volume	Pressures
	%	*mm. Hg*
Left innominate vein	12.0	
Superior vena cava	12.5	
Right atrium	15.6	
	14.2	7–9 (mean)
Left atrium	17.3	
	17.6	
Right ventricle	15.2	
	14.5	73/8
Main pulmonary artery	15.6	75/39
Right pulmonary artery	15.7	50 (mean)
Capacity	19.7	
Oxygen saturation left atrium	89	

TABLE 4

Results of cardiac catheterization

	Oxygen Content by Volume	Pressures
	%	*mm. Hg*
Superior vena cava	12.83	
Right atrium	13.5	15/5
	13.38	
Pulmonary vein	15.61	18/10
Right ventricle	13.54	
	13.74	60/6 (28 mean)
Femoral artery	13.5	105/70
Capacity	15.3	

moderate enlargement. There was a localized systolic murmur heard best to the left of the sternum in the 2nd and 3rd anterior interspaces. Blood studies were within normal limits. Fluoroscopic and x-ray studies of the chest revealed moderate cardiac enlargement (fig. 8).

Cardiac catheterization was performed and the findings are shown in table 3.

A diagnosis of interatrial septal defect of the secundum type with moderately severe pulmonary hypertension was made. He was prepared for surgery and operated on June 13, 1957. A bilateral anterior thoracotomy was made, transecting the sternum without entering the left pleura. A 3-cm. defect was closed by our modification of the Søndergaard technique as described in this paper.

The postoperative course was uneventful except for a period of several days during which he had hallucinations. He was discharged from the hospital on the 16th postoperative day and has continued to have increasing freedom from dyspnea and improvement in strength.

Blood samples taken following closure of the interatrial septal defect and direct palpation of the septum at the time of surgery indicated that the defect was completely closed. He has not been recatheterized.

Case 3. M. K. R., a 3½-year-old girl, was admitted to the hospital for surgical correction of an interatrial septal defect. She was first admitted to the hospital in August 1954 at the age of 6 months for a cardiac work-up because of marked cardiomegaly, failure to gain weight and frequent upper respiratory infections. The child, at the age of 8 months, weighed 9 lb. Physical examination suggested a patent ductus arteriosus. X-rays (fig. 9) revealed marked cardiomegaly with increased pulmonary vascular markings, and a retrograde aortogram confirmed the diagnosis of patent ductus arteriosus. This was surgically interrupted. At the time of surgery it was thought that the child also had an interatrial septal defect.

The child was again admitted to the hospital in August of 1957, her seventh hospital admission for cardiac disease. At this time there was still a story of retarded physical development, frequent upper respiratory infections and ease of fatigue.

Physical examination revealed a small thin child in no acute distress. Her weight was 25½ lb. There was a grade III, low pitched, systolic murmur over the precordium heard loudest in the 2nd intercostal space on the left.

X-rays (fig. 10) demonstrated enlargement of the right atrium and right ventricle with increased pulmonary vascular markings. The electrogram showed sinus tachycardia with right axis deviation, right ventricular hypertrophy and incomplete right bundle branch block. Cardiac catheterization demonstrated an interatrial septal defect and possible abnormal pulmonary venous return. The findings are presented in table 4.

Because it was not felt that a secundum defect had been definitely established and since pressures had not been obtained in the pulmonary artery, the child was prepared for surgery and operated on January 20, 1958, with the pump oxygenator prepared.

Digital exploration of the right atrium through an incision in the right atrial appendage revealed a secundum type defect measuring approximately 1½ by 2 cm. No abnormality in the venous return was noted. Direct pressures taken at this time revealed a systolic pressure of 80 in the right ventricle and 50 in the pulmonary artery (a systolic gradient of 30 mm. of mercury). The secundum defect was closed by the circumclusion technique described in this paper. Following

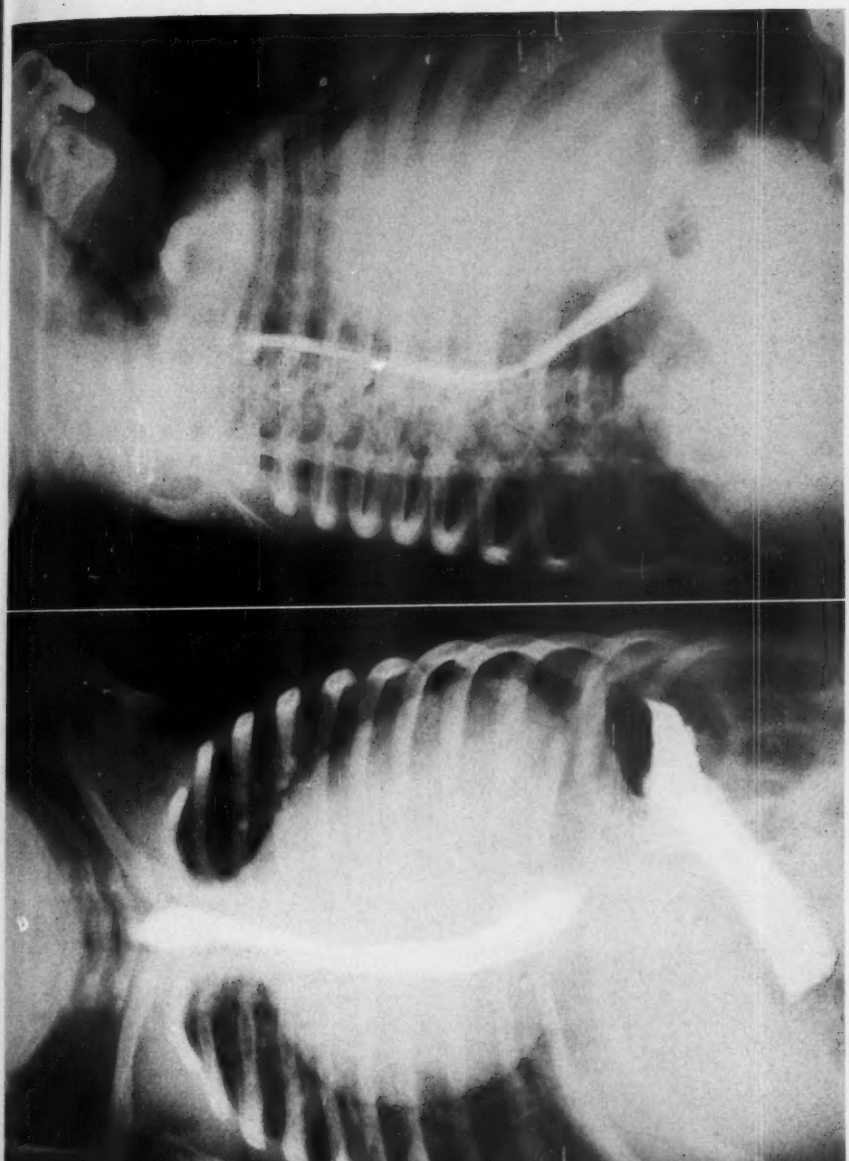

FIG. 9. X-rays on case 3 at the age of 6 months prior to interruption of the patent ductus arteriosis

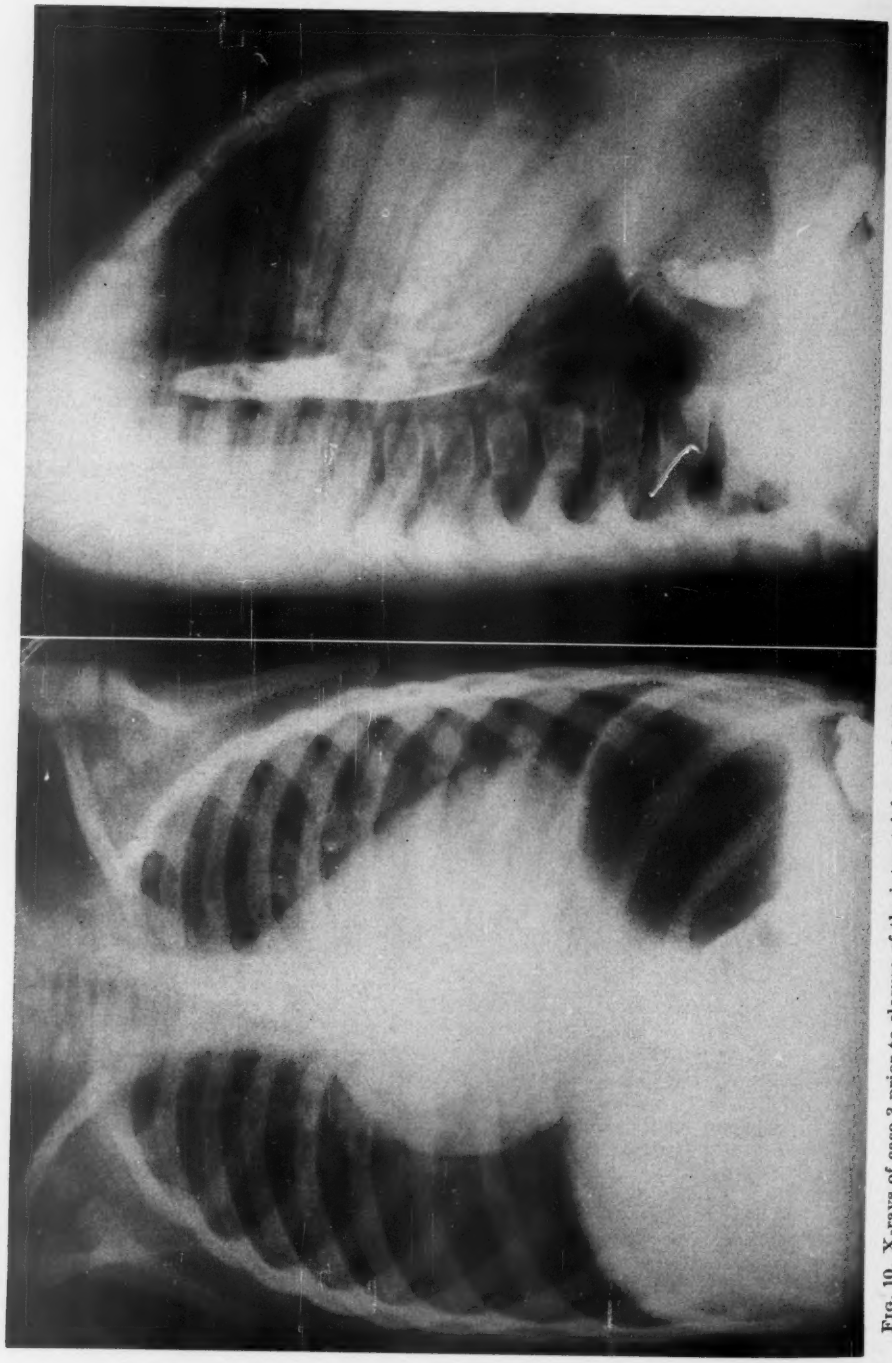

FIG. 10. X-rays of case 3 prior to closure of the interatrial septal defect. The enlarged right atrium and right ventricle and the moderately increased pulmonary vascular markings are demonstrated.

closure of the interatrial septal defect, pressures were again taken. At this time the pressure was found to be 40 mm. of mercury systolic in the right ventricle and the same in the pulmonary artery. Palpation confirmed complete closure of the defect. The child's postoperative course was uneventful and she was discharged from the hospital on her 10th postoperative day. She has not as yet been recatheterized.

Fig. 10. X-rays of case 3 prior to closure of the interatrial septal defect. The enlarged right atrium and right ventricle and the moderately increased pulmonary vascular markings are demonstrated.

SUMMARY

A simple closed technique for surgical correction of secundum type interatrial septal defects is described. Attention is directed to the existence of an anatomic dimple, marking the caudal end of the areolar tunnel of Søndergaard. Introduction of a blunt instrument at this point gives easy access to the areolar tunnel lying at the base of the interatrial septum along the top of the interventricular septum. Thereafter, the technique described by Søndergaard, Crafoord and Bjork is carried out. Twelve experimental procedures and three clinical cases are presented. The authors suggest that past failures with the circumclusion technique have resulted from use of sharp instruments or unanatomic passage of a probe from cephalad with entrance into the atrial chambers or damage to the bundle of His. The technique is not applicable in cases of ostium primum defect or atrio-ventricularis communis where the areolar tunnel does not exist.

In properly selected cases successful closure is effected as surely as by open methods but more simply and without the risk of air embolism, extracorporeal circulation or hypothermia. Its simplicity and sureness have led to its use where interatrial secundum defects have occurred in association with lesions requiring open techniques for proper repair. Three cases are presented.

REFERENCES

1. Bahnson, H. T.: Personal communication.
2. Bailey, C. P., Downing, D. F., Geckeler, G. D., Likoff, W., Goldberg, H., Scott, J. C., Janton, O., and Redondo-Ramirez, H. P.: Congenital interatrial communications. Clinical and surgical considerations with a description of a new surgical technique—atrio-septo-pexy. Ann. Int. Med., *37:* 888, 1952.
3. Bjork, V. O.: Personal communication.
4. Bjork, V. O., and Crafoord, C.: Surgical closure of atrial septal defects. J. Thoracic Surg., *26:* 300, 1953.
5. Bjork, V. O., Crafoord, C., and Varnauskas, G.: Closure of atrial septal defects and pulmonary valvulotomy in a 49-year-old man. Ann. Surg., *40:* 212, 1954.
6. Bosher, L. H., Jr.: Repair interatrial septal defects by a modified Søndergaard technique (circumclusion). Surgery, *41:* 129, 1957.
7. Cohn, R.: Experimental method for closure of interatrial septal defects in dogs. Am. Heart J., *33:* 453, 1947.
8. Cooley, D. A.: Personal communication.
9. DeWall, R. A., Warden, H. E., Lillehei, C., and Varco, R. L.: A prosthesis for the palliation of mitral insufficiency. Dis. Chest, *30:* 133, 1956.
10. Gross, R. E., Pomeranz, A. A., Watkins, E., Jr., and Goldsmith, E. I.: Surgical closure of defects of the interatrial septum by use of an atrial well. New England J. Med., *247:* 455, 1952.
11. Kirklin, J. W.: *International Symposium on Cardiovascular Surgery; Henry Ford Hospital.* p. 364. W. B. Saunders, Philadelphia, 1955.
12. Kirklin, J. W.: Personal communication.
13. Murray, G.: Closure of defects in cardiac septa. Ann. Surg., *128:* 843, 1948.
14. Pemberton, A. H., Kirklin, J. W., and Wood, E. H.: Interatrial-pressure relationships after closure of atrial septal defects in man. Circulation, *15:* 568, 1957.
15. Søndergaard, T., Gøtzsche, H., Ottosen, P., and Schultz, S.: Surgical closure of interatrial septal defects by circumclusion. Acta chir. scandinav., *109:* 188, 1955.
16. Søndergaard, T., Sørensen, H. R., Poulsen, T., and Andersen, I.: Closure experimentally produced atrial septal defects. Acta chir. scandinav., *107:* 485, 1954.
17. Southworth, J. L., and Dabbs, C. H.: *Experience with the Bjork-Crafoord Operation for Closure of Interatrial Septal Defects.* Surgical Forum, American College of Surgeons, p. 3, 1954. W. B. Saunders, Philadelphia, 1955.
18. Watkins, E., Jr., and Gross, R. E.: Experiences with surgical repair of atrial septal defects. J. Thoracic Surg., *30:* 469, 1955.

TREATMENT OF PERITONITIS OF APPENDICIAL ORIGIN WITH AND WITHOUT INTRAPERITONEAL TERRAMYCIN

KENNETH O. ADWAN, M.D., FORREST E. LUMPKIN, M.D., JERRY A. STIRMAN, M.D., AND BEN J. WILSON, M.D.

Dallas, Texas

Although antibiotic therapy has greatly decreased the mortality rate from peritonitis due to gangrenous and ruptured appendicitis, deaths still occur and postoperative morbidity is still frequent.

Beginning with the era of sulfonamides, various chemotherapeutic and antibiotic agents have been placed in the peritoneal cavity, clinically and experimentally, for the treatment of peritonitis. Most of the tested compounds have been reported as successful in controlling bacterial growth, but extreme toxicity or the production of chemical peritonitis made the use of these agents dangerous and untenable. For example, Silvani and associates[10] effectively sterilized the peritoneal cavities of dogs having peritonitis by the intraperitoneal instillation of streptomycin, but all of the dogs died of streptomycin intoxication.

Schweinburg and co-workers,[9] in similar experiments, proved the effectiveness of aureomycin in sterilizing the peritoneal cavity of dogs and compared results of the peritoneal route of administration with results obtained by oral, intramuscular and intravenous routes. Although the intraperitoneal route was the most effective, all of the dogs died from chemical peritonitis.

In 1953 Schatten and Abbott reported a pronounced decrease in mortality rate from peritonitis in dogs by the use of intraperitoneal terramycin. In addition they observed much less peritoneal reaction and a more advanced state of localization of the infectious process than had been found with other therapeutic agents.

At the time of starting our clinical investigation, there were only a few sporadic reports of the use of intraperitoneal Terramycin in man, but since then many references to its clinical use have been published. The results in man have been generally reported as favorable, but these impressions have been derived without the benefit controlled date or even comparative observations. The remarkable effectiveness of parenteral antibiotics plus definitive surgery makes any favorable conclusions concerning adjuvant therapy unreliable if drawn from uncontrolled observations.

In order to test whether intraperitoneal Terramycin had any beneficial effect in peritonitis, a clinical investigation was started in Parkland Hospital in 1955. Assessment of any effect, beneficial or detrimental, would be more accurate, it was decided, if the study were confined to bacterial peritonitis of specific origin; consequently, peritonitis of appendicial origin was chosen. Since the mortality and morbidity of appendicitis are inherently low with conventional modern management, any test of treatment would necessarily have to include a large number of cases, requiring years to accumulate, before significant differences could be established. For this reason only patients with perforated or gangrenous appendicitis were selected for study because the morbidity rates are consistently high following these complications of appendicitis, and with fewer cases a favorable, or unfavorable, effect of one treatment variable would be apparent.

The use of death and survival as criteria of failure or success of treatment is feasible only in animals and has been thoroughly investigated. Morbidity in the survivors, however, cannot be precisely determined in the experimental animal, nor could such data, if obtained, be transposed directly to apply to human beings in whom the disease is modified by removal of the appendix. The most valuable data, therefore, to be derived from a clinical investigation is that pertaining to the question of whether postappendectomy morbidity is less if intraperitoneal Terramycin is added to conventional therapy for perforated and gangrenous appendicitis.

METHODS AND CLINICAL MATERIAL

Included in this analysis are only those patients who had perforation or gangrene of the appendix.

From the Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

All those with only acute appendicitis, even though suppurative, are not included if gangrene or perforation was not found. From 1950 to 1954, in Parkland Memorial Hospital 78 cases of this kind were treated with appendectomy. These were found by review of the operative records and the pathologist's gross and microscopic descriptions of the removed appendix. This group serves as a control series for the 52 cases seen from 1955 through 1957.

In the recent series the presence of perforation or gangrene of the appendix* was established by inspection at the time of laparotomy. If one of these complications was grossly demonstrable, small polyethylene catheters were placed in the peritoneal cavity for the subsequent instillation of a solution containing 1 mg. of Terramycin per milliliter of lactate Ringer's solution. Every 12 hr., 500 ml. of the solution were given slowly as a drip through the plastic tubing. Each infusion required about 10½ hr. Intermittent intraperitoneal antibiotic therapy was usually continued for 24 to 36 hr.

The inadequacy of Terramycin given exclusively in the peritoneal cavity without other parenteral antibiotics is attested to by the death of animals that followed experimentally produced appendicial rupture when Gram positive cocci were cultured from the peritoneal fluid after treatment had begun.[3] Consequently, this investigation was designed to permit the customary use of parenteral antibiotics while Terramycin was given into the peritoneal cavity. In this way no life was placed in jeopardy for the sake of the study, and in addition the patients treated in the previous four years served as controls since the only variation in management established by policy after 1954 was the addition of intraperitoneal Terramycin.

All persons in both groups were admitted to Parkland Memorial Hospital, the city-county hospital for Dallas, and in most instances the resident house staff made the diagnosis, directed preoperative care, performed the operation and administered postoperative supportive treatment. In both periods 80 per cent of hospital admissions to the surgical service were charity cases.

The policies governing the general management of persons with perforated appendicitis were not essentially different in any phase of the 7-year period. Preoperative preparation in those with signs of peritonitis consisted of nasogastric suction, emptying the stomach, parenteral water and electrolytes to replace apparent deficits, parenteral sugar to alleviate ketosis (often present in children), parenteral antibiotics and antipyretics or physical methods of reducing fever. Appendectomy was performed in nearly every instance through a right lower quadrant muscle splitting incision using general inhalation anesthesia. Drainage was usually practiced whenever localized accumulations of pus or necrotic material were encountered in the peritoneal cavity. The drains were brought out through the operative wound which was left open except for the peritoneum. When peritonitis without any purulent localization was encountered, no drains were used. When obvious contamination of the wound edges occurred, the subcutaneous space and skin were not closed.

With changing practices in antibiotic therapy over the last 7 years emphasizing the more generous systemic use of wide spectrum antibiotics and larger parenteral doses of penicillin, one might suppose that the recent group would possess an advantage over the 1950 to 1954 patients. Actually no advantage exists in this regard. The patients treated from 1950 to 1954 were given a mean daily dose of about 1.2 million units of crystalline penicillin and 1 gm. of streptomycin. Approximately the same mean dosage was given to the patients treated from 1955 to 1957. Broad spectrum antibiotics were given systemically, in addition to penicillin and streptomycin, to 55 per cent of the early group and to only 46 per cent of the recent group. The essential difference in the two groups in antibiotic therapy was truly the peritoneal infusion of Terramycin to the patients in the 1955 to 1957 series.

Certain characteristics of the 1950 to 1954 group, when compared to the test series, indicate that the illness was not so severe as that in the test series (table 1). The weighting of the less severe cases in the control series probably arose as a result of the different methods of patient selection that were used in the two groups. In the control series a person was included who had perforation or gangrene of the appendix diagnosed by either gross or microscopic examination of the appendix. In the recent series only the surgeon's gross diagnosis of perforation or gangrene qualified the patient for inclusion in the investigation.

* Over 94 per cent were grossly perforated and the remainder were gangrenous.

The mean age of the patients in the 1950 to 1954 series was 32 years and in the 1955 to 1957 group was 29 years. The frequency of ages by periods is shown in table 2. The morbidity of appendicitis in young children and in the aged has been previously shown to be greater than that in the intermediate age groups.[11] The incidence with which persons over 60 years of age appear in each of the two groups is about equal (15 per cent), but children under 10 years are in greater relative incidence in the test series (25 per cent) than in the control series (6 per cent).

The frequency of complications and severity of illness are related to the duration of symptoms of appendicitis. It is important in evaluating the effects of a therapeutic agent that the control series is not by chance loaded with a large number of persons with a very prolonged history of appendicitis. If it were, the tested therapy would falsely appear to be beneficial. In this study the mean duration of illness prior to appendectomy was 68.6 hr. in the test group and 66.3 hr. in the 1950 to 1954 patients. However, an analysis of the incidence with which operation was performed during various intervals after the onset of appendicitis has more meaning in predicting operative results than does the over-all mean duration of illness in each group. The intervals of time from onset of symptoms until appendectomy is depicted as a frequency distribution in table 3.

TABLE 1

Comparison of operative findings in test and control groups

Operative Findings	Intraperitoneal Terramycin (Total 52 Cases)		No Intraperitoneal Terramycin (Total 78 Cases)	
	No. cases	Per cent	No. cases	Per cent
Gross leakage	33	63	43	55
General peritonitis	29	56	36	46
Localized purulent accumulation	16	31	20	25

TABLE 2

Frequency distribution of patient age

Age	Intraperitoneal Terramycin		No Intraperitoneal Terramycin	
	No.	Per cent	No.	Per cent
yr.				
0–10	13	25	5	6
11–20	12	23	25	32
21–60	19	37	37	48
Over 60	8	15	11	14
Total	52	100	78	100

TABLE 3

Frequency distribution of duration of illness prior to appendectomy

Duration	Intraperitoneal Terramycin		No Intraperitoneal Terramycin	
	No.	Per cent	No.	Per cent
hr.				
1–24	10	19	26	34
24–48	18	35	25	33
48–72	12	23	8	10
Over 72	12	23	18	23
Total	52	100	77*	100

* Duration not known on one patient.

One would expect that the test series in which one-half of the patients came to appendectomy after two days of appendicitis would demonstrate more advanced disease than the control series (1950 to 1954) in which two-thirds were operated on during the favorable 48-hr. period. Accordingly the morbid state encountered at the time of surgical operation actually was worse in the experimental group (1955 to 1957) than in the controls (table 1), and a direct comparison of the postoperative morbidity in the two groups constitutes a severe test of the effectiveness of intraperitoneal Terramycin. Gross leakage of lumenal contents from the appendix was observed during laparotomy in nearly two-thirds of the patients who subsequently received intraperitoneal terramycin, while only 55 per cent of the control patients demonstrated leakage. As a corollary to the higher incidence of leakage, generalized peritonitis was found more often at the time of surgical operation in the experimental group (55 per cent) than in the control group (46 per cent). Localized accumulations of pus were found in conjunction with perforations in about one out of three of the patients who later had Terramycin instilled in the peritoneal cavity, and in only one out of four of those not receiving intraperitoneal antibiotics.

Controlling the investigation by using intraperitoneal terramycin in alternate cases would

have obviated the necessity of having to take into account some of the inherent differences in the two groups, but since the differences are of such a nature as to impose a rigid test on the therapeutic variable, this method of control by comparison with a previous group was adapted. Further, the time required to accumulate adequate numbers by the alternate case method would be inordinately great, about six years, and in the meantime a therapy proved effective in saving animals would have been withheld from one-half of the persons needing it. Our method of control is, therefore, statistically poor but humanely proper.

RESULTS AND COMMENTS

In the control group of 78 patients operated on during the period 1950 to 1954 who had perforated or gangrenous appendicitis there was one death, a mortality rate of 1.2 per cent. In the group of 52 patients receiving intraperitoneal Terramycin who were operated on from 1955 through 1957, there was one death, a mortality rate of 1.9 per cent. These differences are not significant and indicate that the therapy tested was not harmful with respect to survival. In the combined group of 130 patients with gangrenous or perforated appendicitis there was a mortality rate of 1.5 per cent. Thus, for nearly a decade in Parkland Memorial Hospital a very low mortality has attended the most dreaded complications of appendicitis. Table 4 is presented to show the comparative mortality rates in other institutions. Since low death rates following appendicial perforation are enjoyed in many institutions, and some have reported no deaths for periods up to two years, the advances in management of perforated appendicitis must come primarily in the development of measures to prevent morbidity after removal of the appendix.

Table 5 lists the intraperitoneal inflammatory complications that followed appendectomy. A pronounced decrease was observed in intraperitoneal abscess formation when intraperitoneal Terramycin was used postoperatively; about one-third fewer patients required surgical drainage. There was no apparent influence of treatment on the site of localization of pus, since four abscesses were in the pelvis and one was subphrenic in the intraperitoneal Terramycin group, while 10 were in the pelvis, one subphrenic and one subhepatic in the control series. Abscess was diagnosed only when pus was demonstrated, and all required incision and drainage. The incidence of intraperitoneal inflammatory mass, exclusive of abscess, was higher in the patients given an intraperitoneal antibiotic than in those receiving none, but these areas all subsided without evidence of abscess formation and without requiring surgical drainage. If the complications, abscess and in-

TABLE 4

*Mortality in perforated appendicitis**

Authors	Institution	Period	Total No. Cases	Mortality
				%
Culotta and Jordan[2]	V. A. Hospital, Houston	1947–51	74	4.1
Culotta and Jordan[2]	Collected series	1949–56	945	3.2
Cantrell and Stafford[1]	Johns Hopkins, Baltimore	1947–54	219	2.7
Adwan and associates	Parkland Hospital, Dallas	1950–57	130	1.5†
McIver and Broadaway[6]	Bassett Hospital, Otsego Co., N. Y.	1949–55	149	0

* Over 90 per cent of cases in our series were perforated; gangrenous appendicitis with peritonitis but without frank perforation are included.

† One death occurred in patient receiving intraperitoneal Terramycin: 84-year-old patient, with severe pulmonary disease, admitted in stuporous state with intense cyanosis. Died 5th postoperative day. Autopsy showed no peritonitis.

One death in control patient: 64-year-old woman with chronic amebic colitis and pellagra prior to onset of appendicitis. Patient refused surgical operation until 6th day of illness. Gangrenous small bowel with perforation of ileum was found as well as gangrenous perforated appendix. She died 6 hours after operation.

TABLE 5

Intraperitoneal inflammatory complications following appendectomy for perforated or gangrenous appendicitis

Complications	Intraperitoneal Terramycin		No Intraperitoneal Terramycin	
	No. of cases	Per cent	No. of cases	Per cent
Intraperitoneal abscess (all required surgical drainage)	5	9.6	12	15.4
Intraperitoneal inflammatory mass* (all spontaneously subsided)	11	21.1	12	15.4
Fecal fistula	0		0	

* An area of tenderness or induration palpable by rectal or abdominal examination.

TABLE 6

General morbid features following appendectomy for perforated gangrenous appendix

Features	Intraperitoneal Terramycin (Mean Days)	No Intraperitoneal Terramycin (Mean Days)
Fever (oral temperature over 98.6°F.)	7.3	8.7
Ileus*	3.1	2.5
Hospital stay	13.2	13.5

* Time required for return of peristalsis, passage of flatus, absence of distention and removal of nasogastric tube.

flammatory mass are combined, the two groups have an identical incidence, 30 per cent, of development of intraperitoneal complications.

Likely the influence of intraperitoneal antibiotic therapy was not in the prevention of inflammation or in its localization, but primarily was in the reduction of liquefaction necrosis and the prevention of abscess development.

The other morbid features characterizing the postoperative course in each group are enumerated in table 6. Although there was one day's difference in the mean duration of fever and one-half day's difference in the duration of ileus, these are of no significance since the mean hospital stay is identical in both groups. The observation that the duration of ileus is not significantly longer in the persons receiving Terramycin in the peritoneal cavity is of some importance in that many other antibiotics cause chemical peritonitis and one of the manifestations of this chemical irritation is paralytic ileus. Discomfort was felt by some patients who received a rapid flow of 0.1 per cent Terramycin solution in the abdominal catheters, but when the flow rates were decreased the pain abated.

Wound abscess requiring drainage was found in 7 patients, or 13.4 per cent, of those in the intraperitoneal antibiotic group and in 9, or 11.4 per cent, of the control series. The similar incidences of occurrence in the two groups tend to confirm what one might predict; namely, that the postoperative intraperitoneal instillation of antibiotic would have essentially no effect on the development of extraperitoneal wound infections.

DISCUSSION

This study was designed to determine whether intraperitoneal antibiotic could minimize postappendectomy morbidity in patients having perforation of the appendix. A pronounced difference was noted in the incidence of intraperitoneal abscess formation, from 15.4 per cent to 9.6 per cent, when intraperitoneal Terramycin was given. The finding that one-third fewer persons required surgical drainage of pus in the postappendectomy period is considered to be an effect of the intraperitoneal Terramycin and represents a clinically significant improvement in management of persons having perforated appendicitis.

Without a weighting factor which takes into account the inherently favorable characteristics of the control group, a value of $p = 0.1$ is found by applying the test of significance of proportionality. This test cannot be expected to give a valid representation of significance in this study because its application depends upon the similarity between the control and experimental groups. By chance some group characteristics which tend to weigh favorably on the results are found to occur more frequently in the control patients than in the experimental patients. These characteristics are: (1) There are fewer young children in the control group. (Young children typically are beset by more complications of appendicitis than older children or adults.) (2) More patients in the control group had appendectomy performed within 48 hr. of onset. (3) More favorable findings occur at the time of laparotomy; that is, there are fewer instances of generalized peritonitis, of free leakage from appendicial perforation and of contiguous abscesses.

The modest total mean dose of Terramycin and the brief mean period of time that intraperitoneal instillation was used might be limiting factors, peculiar to this study, which minimized differences in the two groups. It is contemplated that additional observations will be made using a larger total dose over a longer time period. If dosage has been a retarding influence in the present study, the contemplated experiments will yield magnified differences. By using random selection of treatment schedules in patients with similar illnesses, a statistical determination of significance will possibly be more applicable.

A larger dose of Terramycin will be the next variable investigated rather than another antibiotic because Terramycin is the safest of the antibiotics that are effective intraperitoneally. Tetracycline has been found to be unsatisfactory

for use in the peritoneal cavity because of the development of chemical peritonitis.[7] Some favorable reports concerning the intraperitoneal instillation of neomycin in peritonitis have appeared,[7] and the advantage of decreased discomfort at the time of instillation is given as the reason for its use. This is a minor advantage compared to the real peril of respiratory failure that may attend the intraperitoneal use of neomycin. Apnea was encountered once in Parkland Memorial Hospital when neomycin was being injected into the lumen of the bowel at the time of laparotomy and some of the 1 per cent solution was inadvertently spilled into the peritoneal cavity. In Dallas three other instances of respiratory arrest incident to intraperitoneal neomycin have been brought to the attention of the authors. Several other descriptions[4,5] of this complication have appeared, and, in fact, Poth[6] observed apnea in some of his early experiments using neomycin in animals.

SUMMARY

1. Terramcyin solution, 1 mg. per ml. of lactate Ringer's solution, has been given into the peritoneal cavity of 52 persons following appendectomy for perforated or gangrenous appendicitis. The results of treatment in these patients have been compared with the results in 78 persons with perforated or gangrenous appendicitis to whom intraperitoneal Terramycin was not given.

2. The slow instillation of Terramycin as 0.1 per cent solution through an indwelling plastic tube was not attended by signs of chemical peritonitis or toxicity and was apparently without harm. The duration of postoperative fever and ileus was not significantly affected by intraperitoneal antibiotic therapy.

3. When intraperitoneal Terramycin was used following appendectomy for perforated and gangrenous appendicitis, one-third fewer intraperitoneal abscesses formed than when it was not used. In the testing procedure an inherent disadvantage was placed upon the hypothesis that intraperitoneal therapy is of value, for intraperitoneal Terramycin was given to the patients with more severe disease; consequently, the reduction of pelvic and subphrenic abscesses from 15.4 to 9.6 per cent represents a significant achievement in the management of peritonitis.

4. No significant difference in the frequency of wound abscesses was noted in the two groups.

5. No antibiotic other than Terramycin is thought to be so safe, yet effective, when given into the peritoneal cavity of man in the treatment of bacterial peritonitis.

6. The optimal dosage and duration of intraperitoneal Terramycin therapy of peritonitis of appendicial origin has not been determined. This is to be the subject of further investigation.

REFERENCES

1. Cantrell, J. R., and Stafford, E. S.: The diminishing mortality from appendicitis. Ann. Surg., *141:* 749, 1955.
2. Culotta, R. J., and Jordan, G. L., Jr.: Acute appendicitis: analysis of 387 cases. Am. Surgeon, *23:* 356, 1957.
3. McIver, M. A., and Broadaway, R. K.: Acute appendicitis in a rural community. Series III: 25 year summary. Ann. Surg., *145:* 552, 1957.
4. Middleton, W. H., Morgan, D. D., and Moyers, J.: Neostigmine therapy for apnea occurring after administration of neomycin. J. A. M. A., *165:* 2186, 1957.
5. Pridgen, J. E.: Respiratory arrest thought to be due to intraperitoneal neomycin. Surgery, *40:* 571, 1956.
6. Poth, E. J.: Critical analysis of intestinal antisepsis. J. A. M. A., *163:* 1317, 1957.
7. Schatten, W. E.: Intraperitoneal antibiotic administration in the treatment of acute bacterial peritonitis. Surg. Gyn. Obst., *102:* 339, 1956.
8. Schatten, W. E., and Abbott, W. E., Intraperitoneal administration of terramycin in treatment of experimental peritonitis. Surg. Gynec. & Obst., *97:* 445, 1953.
9. Schweinburg, F. B., Glotzer, P., Rutenburg, A. M., and Fine, J.: The therapeutic effect of Aureomycin in experimental peritonitis in the dog; parenteral therapy. Ann. Surg., *134:* 878, 1951.
10. Silvani, H. L., Rotwenberg, S., Warmer, H., Amluxen, J., and McCorkle, H. J.: Laboratory and clinical experiences with streptomycin therapy in the management of infections of intestinal origin. Surg. Gynec. & Obst., *85:* 721, 1947.
11. Thieme, E. T.: Appendicitis—a 15 year survey. A. M. A. Arch. Surg., *70:* 207, 1955.

THE OPEN TREATMENT OF WRINGER INJURIES IN CHILDREN

ERNEST POULOS, M.D.

Dallas, Texas

Since MacCollum first coined the term "wringer arm" in 1938 and reported 26 cases,[8] a number of reports have appeared in the literature expanding the total number to well over 1800.[1, 5-11] There are probably several thousand cases which have not been reported. It is likely true, as has recently been stated, that the incidence of this injury is on the decline[10] since the advent of the spin dryer. However, in charity institutions where the clientele still employ the washer with wringer attachments the occurrence of this type of injury is frequent. The magnitude of this problem is exemplified by the fact that a child is presented to Parkland Memorial Hospital for treatment of a wringer injury every 10 days.

The mechanism of injury and the factors involved in producing the varying degrees of severity of the injury have been adequately described.[4, 5, 8-10] However, the treatment of these injuries demands closer scrutiny. Every author who has written on the subject of wringer injuries emphasizes the importance of the use of pressure bandages. In fact, many state that the patient has been improperly managed if external pressure is not applied to the injured extremity. This author disagrees with this hypothesis, for reasons to be discussed later, and as a consequence no pressure bandages were used in the treatment of any patient in this series. In order to evaluate this factor and other factors essential to the management of wringer injuries, this study was undertaken.

From August 1956 through November 1957, 48 persons with wringer injury were admitted to Parkland Memorial Hospital, which is the charity hospital for the city and county of Dallas. These 48 patients were consecutively presented to the emergency room with wringer injuries of the upper extremities and form the basis of this report. The patients were all children ranging from 16 months to 11 years of age. The average age for the group was 4.3 years. The average time of delay from injury to admission was 4.5 hr. One child did not appear for therapy until two days after injury, while two cases were not presented until the fourth day.

The principal physical findings at the time of admission were confined to the injured extremity and are summarized in figure 1. It can be seen that edema was the most consistent finding and was present in 92 per cent of the children.

Friction burns were present in 64 per cent of the extremities and the most frequent site of involvement was the forearm. Only 2 of 25 forearm burns were third degree, while 2 of 4 antecubital fossa and 2 of 6 hand burns were of third degree depth. Hematomas were present in 10 per cent but they were small. Ten per cent had lacerations of the hand and in the web spaces of the fingers. These were not more than 1½ cm. long nor more than 3 mm. deep. Dislocation of the metacarpophalangeal joint was found in two children; these were readily reduced. Only one greenstick fracture was detected. Gangrene of the first and second fingers was present in only one patient at the time of admission. Small collections of subcutaneous fluid were present in two cases (4 per cent). In no instance was there evidence of nerve or vascular injury except in the girl with the gangrenous fingers cited above; her radial pulse was of normal amplitude and capillary flow was normal in the remaining digits.

The management of the patients in this series consisted of elevation, cleansing and debridement, antibiotics, tetanus prophylaxis, early skin grafting,[3] aspiration of fluid collections and frequent evaluations of the neurocirculatory state of the injured part. The complete absence of dressings, except for fine mesh gauze in the web spaces and axilla, and the complete absence of compression bandages represent gross deviation from principles of management that others advocate.

RESULTS

The results of this program of therapy can best be evaluated by the rate of disappearance of edema, progression of necrosis of skin, the fate of lacerations, the number of skin grafts and ampu-

From the Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

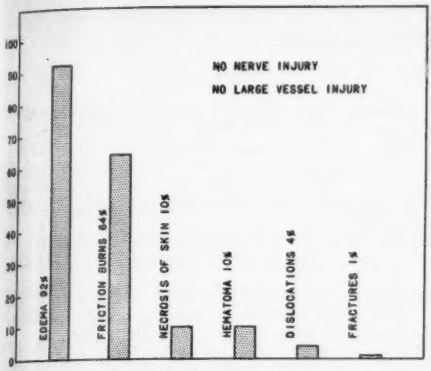

FIG. 1. Graph showing condition of wringer arm patients upon admission to the hospital.

tations required, the occurrence of infection and the functional result obtained. The edema disappeared in from 1 to 4 days except in one case which took 7 days to resolve. Areas of necrosis did not progress in size nor apparently in depth, thus emphasizing the lack of need of compression bandages or occlusive dressings. The five lacerations which were left open healed rapidly while those which were sutured required removal of sutures, in one instance because of infection and in another because of inadequate debridement. Only five skin grafts were required and these were split thickness. One involved the forearm and the antecubital fossa. The other four were required on the forearm, the antecubital fossa and the hand. Amputation of two fingers was performed in one patient whose fingers were gangrenous at the time of admission. Active clinical infection developed in three children and these responded well to antibiotics. Some of the patients requiring grafts developed temporary muscle weakness and shortening as a result of disuse, but these responded to physiotherapy and the late functional result was good in all. A summary of the patients requiring surgical therapy is presented in table 1.

TABLE 1

Summary of need for surgical therapy

Surgical Therapy Used	Patients
	%
No surgery required	74
Initial debridement or suture repair	14
Skin grafts	10
Amputations	2
Fasciotomy	0

DISCUSSION

It is generally agreed by those who write on the subject of wringer injuries that the most important single factor comprising proper treatment is the use of compression bandages. A large number of clinical reports supports this contention.[1, 2, 4, 6, 7, 9-11] The only experimental work on this subject has been reported by Entin,[4] who, utilizing dogs and rats, found that hyaluronidase and/or pressure dressings increased tissue survival. However, he also demonstrated that under some circumstances the tissue loss was greater when pressure dressings were used.

It is granted that the disappearance of edema can be hastened by the use of pressure dressings, but this is accomplished at the expense of increasing the pressure to the skin and to the depths of the extremity. When the pathology of the injury is considered, that is, hemorrhage and edema in the superficial and deep compartments, it can be realized that the circulation is imperiled from within by the pressure incident to swelling. To jeopardize the circulation further by superimposed external pressure of any magnitude is illogical, and may even contribute to the production of ischemic necrosis. Instead, it may be necessary to release subcutaneous pressure by the use of relaxing incisions as advocated by Speed[12] and also to release pressure in muscle bundles by fasciotomy in the flexor and extensor compartments. This was not found to be necessary in any of these cases since evidence of impaired blood flow never developed.

Other obvious disadvantages to pressure dressings are that they are expensive to the patient, a time consuming nuisance to the physician, and capable of hiding important early signs of vascular insufficiency.

For the reasons given above no pressure dressings were used in any of the patients treated in this series and from the results obtained their omission did not adversely influence the outcome. While the use of fasciotomy was not indicated in any of these patients, the presence of extreme tightness in the deep muscular compartments or diminution in digital capillary flow dictates that fasciotomy be performed immediately. The need for its use is well demonstrated by the photographs in the article by Luck and Maddux,[7]

which show progressive necrosis of the hand and digits. Tension in the muscular compartments and skin tightness were probably compounded by the use of external pressure.

Lacerations incurred in this type of injury are best treated by allowing them to heal spontaneously or by employing secondary closure techniques, for the use of primary suture of contused skin is doomed to fail.

The results of this clinical study indicate that extremities injured by wringers can successfully be treated by the open method, and that the wise application of surgical principles rather than adherence to a factor which is thought to be the *sine quo non* in the therapy of wringer injuries will be productive of good functional results.

SUMMARY AND CONCLUSIONS

1. The findings and management of 48 cases of wringer injuries in children are presented in detail.

2. All wringer injuries should be admitted to the hospital for observation and prevention of serious complications.

3. While most wringer injuries are mild, a few will require extended hospitalization for skin grafting and physiotherapy.

4. The lack of use of compression bandages did not adversely alter the outcome of these patients. It is suggested that compression bandages may be harmful, and it is recommended that their use be abandoned.

REFERENCES

1. Allen, H. S.: Wringer injuries of the the upper extremity. Ann. Surg., *113:* 1101, 1941.
2. Bell, J.L., Mason, M. L., and Allen, H.S.: Management of acute crushing injuries of the hand and forearm over a five-year period (1948–1952). Am. J. Surg., *87:* 370, 1954.
3. Edgerton, M. T., Jr.: Immediate reconstruction of the injured hand. Surgery, *36:* 329, 1954.
4. Entin, M. A.: Roller and wringer injuries: clinical and experimental studies. Plast. & Reconstruct. Surg., *15:* 290, 1955.
5. Gross, R. E.: *Surgery of Infancy and Childhood.* W. B. Saunders Company, Philadelphia, 1953.
6. Hausmann, P. F., and Everett, H. H.: Wringer injury. Surgery, *28:* 71, 1950.
7. Luck, J. V., and Maddux, R.: Washing machine wringer injuries in children. Gen. Pract., *12:* 87, 1955.
8. MacCollum, D. W.: Wringer arm: a report of twenty-six cases. New England J. Med., *218:* 549, 1938.
9. MacCollum, D. W., Bernhard, W. F., and Banner, R. L.: The treatment of wringer-arm injuries. New England J. Med., *247:* 750, 1952.
10. Posch, J. L., and Weller, C. N.: Mangle and severe wringer injuries of the hand in children. J. Bone & Joint Surg., *36-A:* 57, 1954.
11. Schulz, I.: Wringer injury. Surgery, *20:* 301, 1946.
12. Speed, K.: Discussion of paper presented by Irwin Schulz. Surgery, *20:* 301, 1946.

BONE REPAIR—SOME CLINICAL APPLICATIONS IN MODERN FRACTURE MANAGEMENT

C. F. GREGORY, M.D.

Dallas, Texas

As Girdlestone[4] has said most eloquently, "There is danger inherent in the mechanical efficiency of our modern methods; danger lest the craftsman forget that union (in bone) cannot be imposed but may have to be encouraged. For a bone is a plant with its roots in the soft tissues, and when its vascular connections are damaged, it often requires not the technique of a cabinet maker, but the patient care of a gardener." With our broadened knowledge of how bone develops, matures and is sustained in health, this admonition is more valid now than ever.

Germane, if not imperative to a discussion of these factors, then is a brief review of some points of the anatomy and physiology of bone. Far from being inert physiologically, bone is really quite active. This is especially true of the turnover in ions which are present in the mineral lattice work and its shell of hydration. Yet biologic activity at the cell level proceeds at comparatively slow rates. In both events, however, an adequate provision for blood and extracellular fluid must be maintained, and it is within the systems which have evolved for this purpose that the vulnerability of bone is encountered.

Figure 1 depicts the three systems which have as their ultimate objective the transport of nutrients and oxygen to the cell and the removal of metabolites from it. Part *I* shows that the organ bone is supplied with blood *via* two sources; the nutrient artery (*A*), and the metaphyseal-periosteal vessels (*B*). Anastomosis of these two sources will normally sustain the most of this circulation should one of the sources be sundered. The second system is again a vascular one, and part *II* depicts the organization of it within bone tissue. It is comprised of blood vessels lying within the linearly disposed Haversian canals (*C*), and the transversely disposed Volkmann's canals (*D*). It is these latter which form the ultimate anastomosis between the endosteal and periosteal sources.

From the Division of Orthopedic Surgery, Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

Because extracellular fluids do not easily diffuse through a calcified matrix, some alternate provision is necessary to provide conduction of blood born nutrients to the cells. Thus in scheme *III* are depicted the fluid containing canaliculi (*E*) radiating in a fashion to connect lacunae (*F*) with the Haversian canal (*C*) and with each other. Ham[5] has estimated the maximum range of diffusion in cancellous bone rarely exceeds 2 mm , and probably no osteocyte long exists if it be farther than that distance from an Haversian or Volkmann's canal in cortical bone.

Vulnerability of bone to disruption is obviously least in the nutrient artery-periosteal system where effective anastomosis is most diffuse; it is greater when a rigid walled Haversian system is disrupted, with consequent rupture of its contained vessel; and it is greatest when a canalicular system is disrupted, thus completely depriving encaptured osteocytes of their only source of sustenance.

While the high incidence of avascular necrosis in certain fractures (*i.e.*, the head of the femur, navicular or talus) is well known, it is perhaps less appreciated that some degree of avascular necrosis attends the fragments of any fracture. Further, the extent of such necrosis may well be governed by the subsequent management of the fracture.

Bones grow by the peripheral accretion of new bone tissue because bone tissue has not the capacity for interstitial growth. Likewise, in a bone which has been fractured, repair is in the main a matter of the peripheral accretion of new bone. This repair bone (or callus) may be largely removed when the fragments are united and the fracture line obliterated. Such remodeling of the fracture repair site is another invocation of the phenomenon regularly employed during growth for sustaining a continuity of form in growing bones, even though linear growth is accomplished by accretion at each of its ends along the full width of its epiphyseal plates.

Thus, the child who sustains a fracture may heal it more rapidly and remodel it more com-

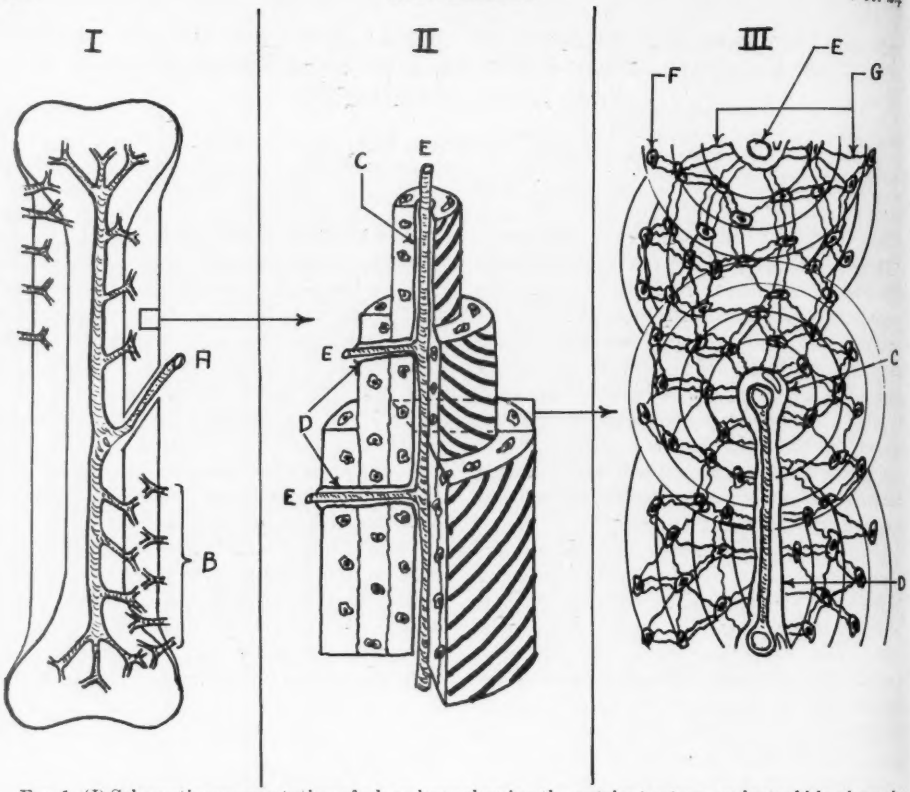

FIG. 1. (*I*) Schematic representation of a long bone showing the nutrient artery, endosteal blood supply (*A*) and the metaphyseal-periosteal system (*B*) with their anastomosis. (*II*) Schematic representation of an osteone with its central Haversian canal (*C*) and transversely disposed Volkmann's canals (*D*) both containing arteries (*E*). (*III*) Schematic representation of a transverse section through three adjacent osteones to illustrate the concentric lamella, Haversian canal (*C*), Volkmann's canal (*D*), lacunae with their osteocytes (*F*) and the multiple radiating canaliculi (*G*) which join lacunae and canals, and thus provide a means for diffusion of fluids, nutrients and metabolites from blood to cells and reverse.

pletely (if it is imperfectly reduced) than would an adult with the same pattern. Figure 2 is a common example of this mechanism. Yet the adult can heal and does remodel his fractured bones to a limited extent. McLean and Urist[7] have suggested that the recall of the osteogenic cells of the periosteum and endosteum from their dormant state in the adult to one of active bone formation is properly called cellular modulation. Delayed union and certainly nonunion are more frequent in the adult, related perhaps in part, to the latent period required for endosteal and periosteal stimulation.

If repair of fractures is effected largely by the peripheral accretion of new bone, it becomes a surface phenomenon. Consequently, the surface area available for its apposition must be a factor for consideration. It is interesting that in our experience, nonunion is most frequently encountered in the shaft bones of vigorous, healthy adults and least so in children and the less active older persons. Studies of bone in both these age groups have shown them to be more porous than in the middle aged group. Such porosity implies a greater surface area for bond between preexistent fragment bone and repair bone.

Finally, repair bone, wherever it is formed, is in histologic structure and arrangement, very similar to fetal bone. Charnley[2] has shown that it may be bent without breaking and thus permit progressive deformity while yet united, if the fracture is left unguarded. It is no surprise to know, therefore, that late deformity at a "united" fracture site may occur. It has puzzled many.

FIG. 2. (*A*) Fracture of distal radius in child age 3. (*B*) Acceptable reduction by closed means. (*C*) Patient did not return for 1 month. By then position had been lost. Not correctable except by open operation. This was *not* done. (*D*) Extent of restoration of normal contour in only seven weeks. The bone has since completely remodeled itself.

The surgeon's obligation to the patient with a fracture is to take every advantage in utilizing natural healing tendencies and to avoid any circumstance which might prejudice a successful outcome. For, to repeat from Girdlestone,[4] "union cannot be imposed upon a fractured bone."

The surgeon's objective is a promptly united fracture resulting in a limb with normal length, strength and mobility.

While the method for achieving this objective is varied, the basic steps are to deal with any related soft tissue injury first and then to gain and maintain a reduction of the fractured bone. A satisfactory reduction must include some degree of apposition of the bone fragments, proper alignment in both linear and rotary planes and adequate length for that limb, if gaining such restitution does not compromise the first two. Admittedly, exceptions can be found for many individual cases. Yet by these principles there is established the first of three essentials to union in most cases of fracture.

The second essential to successful union is generally considered to be adequate immobilization for an adequate period of time. This also varies widely in the time required.

Contact-compression was enunciated and demonstrated as the third essential to successful union by Dr. George Eggers.[3] It considers the pathophysiologic reality of bone resorption at the apposed cortical margins of reduced shaft fractures especially and the desirability of permitting such fragments to move toward each other as such resorption takes place. This point is most important in those fractures to be dealt with by open reduction and internal fixation.

We shall not attempt to consider all of the factors which may govern the success or failure of fracture management. However, if one decides upon open operation to gain reduction and/or to maintain the reduction by some method of internal fixation, certain pitfalls are present which are not always readily appreciated. Sometimes these appear a week after open reduction and fixation and sometimes only after several months.

FIG. 3. (*A* and *B*) Isolated fracture of the distal shaft of the radius immediately after open reduction and fixation by a single screw. Position, length and alignment are acceptable. (*C* and *D*) Three features of its inadequacy: resorption and telescoping have occurred with separation of the fragments; rotation has occurred about the long axis of the single screw; there is now a consequent subluxation at the distal radio-ulnar joint.

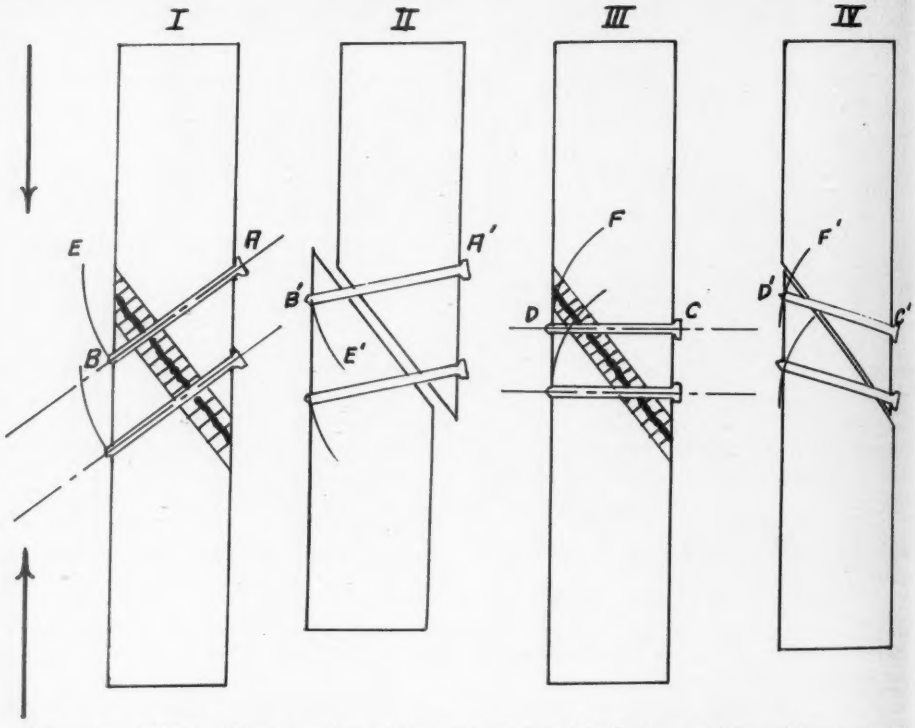

FIG. 4. (*I* and *III*) An oblique fracture pattern in two bone shafts. The screws *A–B* and *C–D* represent two different inclinations for screw insertion in the same fracture pattern. The cross hatched areas represent areas of potential bone resorption in each fragment. The arrows represent the direction of fragment movement due to muscle tone. *E* and *F* represent the arcs which might be described should absorption and linear telescoping take place. (*II* and *IV*) The positions that might be anticipated after telescoping, and the variation in the fragment positions due to the differing inclinations of the screws in the two illustrations. In theory it appears that the screw introduced at right angles to the long axis of the involved bone provides the best opportunity for continued apposition of fragments should absorption and telescoping occur. See also fig. 5. This theory has had some practical expression in the work of Arizmanoglou and Skiadaresis.[8]

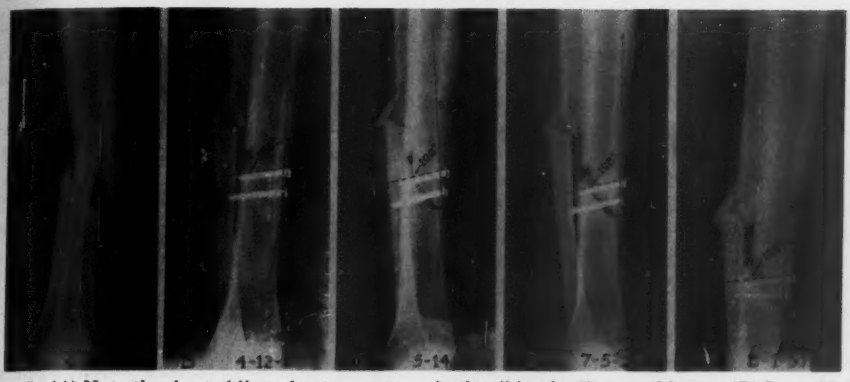

FIG. 5. (*A*) Note the short oblique fracture pattern in the tibia of a 46-year-old man. (*B*) Immediately after open reduction and fixation with two screws. Note that the screws have only approximated the principle of placing them at right angles to the long axis of the involved bone. (*C*, *D* and *E*) Note that the fibula has united, but continued absorption has only widened the gap between the tibial fragments. The screws have served only to hold them apart for the healed fibula prevented telescoping to any significant extent. The ultimate result in this case was non-union.

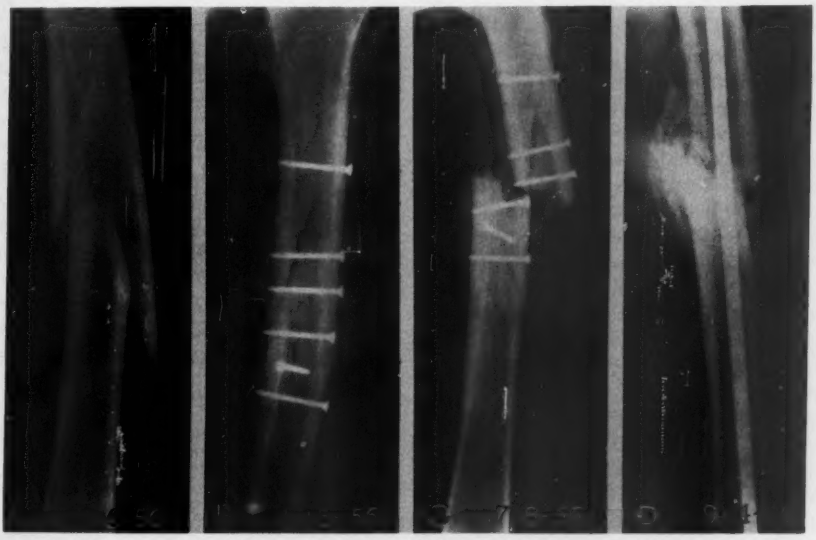

FIG. 6. (*A* and *B*) A spiral oblique and comminuted fracture of the femoral shaft of an elderly male reduced and maintained by open operation and the insertion of multiple screws. (*C*) A fresh fracture incurred 5 months later. Some healing had occurred by peripheral bridging callus. (*D*) Intramedullary fixation after second procedure to remove screws and obtain and maintain reduction. A remarkable proliferation of callus is to be noted.

Many purely mechanical problems are faced. As an example, consider the isolated fracture of a radius in its shaft. This fracture often fails to respond to closed management, and it is the experience of many (6) that open reduction and adequate fixation is very frequently necessary to a satisfactory result. The fracture pattern is often gently oblique. It is tempting to fix it with a single screw. The fixation may seem quite stable at the conclusion of the operation, but subsequently, in a plaster cast, and with the restoration of muscle tone when the relaxation of anesthesia is dissipated, displacement appears again. Two factors are in operation here. First is the simple fact that when a single screw is employed, rotation can still occur about its long axis. This same

tendency may well be enhanced by the second factor of bone resorption at the fracture surfaces. Unless the fracture pattern is advantageously self-locking when the fracture is reduced, the rotary and angular displacement depicted in figure 3 may appear. The only effective recovery from it is reoperation and adequate internal fixation. While intramedullary fixation may prevent this redisplacement, it carries its own problems in a curved bone such as the radius. The reader is referred to the excellent article by Smith and Sage[8] on that subject.

If a bone is large enough and the obliquity of the fracture great enough to provide surface for the insertion of two screws, rotation about the axis of the screws can be averted. Yet the use of two or more screws in the oblique fracture poses additional problems. Figure 4 is a schematic representation of the fate of fragments at a fracture site should the fragments tend to telescope, depending upon the inclination at which the screws are inserted. Even where no such telescoping occurs, the fracture site may fail to unite promptly, being held apart by the very device intended originally to assure their continued apposition. Figure 5 is an example of the latter situation. When this fracture site was examined at operation for bone grafting and fixation with a Lottes' nail, the screws were loose enough, but loose too late to permit apposition when it might have been useful. It is our experience that such failure will most frequently attend the use of screws in short oblique fractures of this pattern. It is less so in the long oblique and least frequent in the true spiral fracture.

Figure 6 illustrates a long spiral oblique pattern of fracture in the femur shaft. As shown, an anatomic reduction of the fragments was obtained and was effectively maintained by multiple transfixing screws placed at right angles to the long axis of the femur. Union occurred. Yet such a reduction and its fixation were accomplished only by considerable stripping of soft tissues from this area of the injured shaft. Such stripping of periosteum and periosteal vessels combined with the disruption of the endosteal (nutrient artery) vessels might well render considerable portions of this bone avascular, and therefore nonviable. It is not surprising then to note a transverse fracture superimposed upon the original fracture site, induced by a minor trauma some eight months later.

Since the original reduction and fixation were accomplished only after considerable stripping of soft tissues, the opinion that much of the bone tissue was thus rendered avascular was subsequently sustained by the appearance of hard, yellow, nonbleeding bone encountered at the second fracture site when the limb was re-entered for removal of the screws and the insertion of an intramedullary rod to maintain reduction. Union was promptly obtained, through peripheral bridging callus, but actual union of the fragments where they are apposed and the restoration of normal bone strength will be a long time developing.

SUMMARY

In these paragraphs some salient features of the anatomy and physiology of bone in the growing and mature person have been considered. Some of the pathophysiology of traumatized bone tissue has been mentioned. Some of the limitations of fixation devices have been considered. No mention has been made of the constant specter, infection, which sits ever at the surgeon's side and may convert a well intended effort at hastening union to the catastrophe of an infected nonunion. Yet these are but fragments of the concept that there really is no magic in the devices so often used to maintain a "nice reduction." In fact the procedures employed to effect their application may prejudice the "objective" of treatment far more than a less perfect reduction of the fracture fragments obtained by closed methods of reduction and immobilization.

REFERENCES

1. Arizmanoglou, A., and Skiadaressis, G.: Study of internal fixation by screws of oblique fractures in long bones. J. Bone & Joint Surg., *34A:* 219, 1952.
2. Charnley, J.: *Modern Trends Series* (*Modern Trends in Orthopaedics*). Edited by Sir Harry Platt. Paul B. Hoeber, Inc., New York, 1950.
3. Eggers, G. W. N., Shindler, T. O., and Pomerat, C. M.: The influence of the contact-compression factor on osteogenesis in surgical fractures. J. Bone & Joint Surg., *31A:* 693, 1949.
4. Girdlestone, G. R.,: The treatment of fractures in the light of their ischaemic complications. J. Bone & Joint Surg., *14:* 755, 1932.
5. Ham, A. W.: Some histophysiologic problems peculiar to calcified tissues. J. Bone & Joint Surg., *34A:* 701, 1952.
6. Hughston, J. C.: Fractures of the distal radial shaft-mistakes in management: J. Bone & Joint Surg., *39A:* 249, 1957.
7. McLean, F. C., and Urist, M. R.: *Bone—An Introduction to the Physiology of Skeletal Tissue.* University of Chicage Press, J. B. Lippincott, 1955.
8. Smith, H., and Sage, F. P.: Medullary fixation of forearm fractures. J. Bone & Joint Surg., *39A:* 91, 1957.

THE USE OF EPIDURAL BLOCK AS AN INDICATION FOR CORDOTOMY

KEMP CLARK, M.D., AND KARL ERWIN, M.D.

Dallas, Texas

Pain accompanying chronic illness, either metastatic or inflammatory, is a frequently encountered symptom. It is a purely personal one without any satisfactory form of objective measurement being available. Also, it is a complaint which may be relieved by neurosurgical intervention. Every patient sustaining a chronic illness may have manifest psychologic changes, and sometimes these changes may take the form of pain. The problem becomes more perplexing in that the symptom of pain may be both functionally and organically based. Every physician dealing with chronic illness has been presented with this dilemma. Usually he can make an evaluation between organic and functional basis for pain by his clinical knowledge and evaluation of the patient. Differential epidural block is by no means a routine procedure. We have used it in four cases in which the separation of organic and functional components of complaints of intractable pain could not be made by other techniques.

Epidural anesthetic block administered by a catheter placed in the epidural space at the appropriate level causes the patient little or no discomfort during its administration. It does not have the dangers of spinal anesthesia, so it seems ideally suited, combined with certain pharmacologic agents, as a measure of determining the source of pain in these doubtful cases. The technique consists of placing an epidural catheter under local anesthesia at the clinically appropriate level. Following the placement of the catheter, normal saline, ¼ per cent procaine, 1 per cent procaine and 2 per cent pontocaine were administered at random through the catheter and the patient's reactions to each of these compounds ascertained.

The catheter can be left in place for 48 hr. to verify the results. Normal saline produces no relief of pain when introduced epidurally; ¼ per cent procaine produces relief of pain lasting for 15 to 30 min., 1 per cent procaine produces pain relief lasting approximately 30 min. to 1 hr., and pontocaine produces relief lasting from 2 to 4 hr. It is not necessary to administer enough of these latter compounds to cause motor paralysis for pain relief to occur.

Briefly, the value of this procedure is indicated by the following two case reports.

The first patient, a 34-year-old white woman with a diagnosis of porphyria, had been followed in Parkland Memorial Hospital for a number of years. Her principal complaints were of lightning-like, severe pain in the lower abdomen and extremities. She required large doses of narcotics and was severely addicted to their use. The patient's personality had undergone some deterioration due to porphyria or to the drug addiction. Thus, it was extremely difficult to evaluate the pain problem in the light of an organic lesion capable of producing pain, narcotic addiction and psychiatric disturbances, all of which could be interrelated. Epidural block at the level of T-3 through T-6 produced complete relief of the patient's pain with the administration of the procaine and pontocaine solutions. This relief lasted for the appropriate time. Normal saline produced no relief of the pain at any injection. Subsequently, the patient underwent a bilateral thoracic cordotomy. This resulted in complete relief of pain with spontaneous cessation of the use of narcotics. Pain relief has been persistent for 15 months.

The second patient, a 51-year-old white woman, was seen because of recurrent attacks of sciatic pain in the left leg. The patient had been explored on two previous occasions at other hospitals for a herniated nucleus pulposus at the L-5, S-1 interspace. The patient was a suspicious, withdrawn, tense woman with marked evidence of emotional instability. Neurologic examination revealed an area of hypesthesia in the S-1 nerve root distribution on the left and a diminished ankle jerk on the left side. It was felt the patient had either a recurrence of her herniated nucleus pulposus or arachnoiditis involving the S-1 nerve toor. Because of her personality pattern, plus her neurologic deficit compatible with organic disease of the nerve root, differential epidural block was

From the Division of Neurosurgery, Depart- of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

performed. No relief of her symptoms was obtained by any of the compounds introduced epidurally. Therefore, it was concluded that her pain was psychogenic in origin. Subsequent events, manifested by an acute psychotic episode, seem to bear out this assumption.

The use of differential epidural block represents, in part, a manipulative placebo approach to the differential diagnosis of organic and functional pain. However, unlike the administration of a drug systemically, with its associated general pharmacologic and psychic effects, the direct administration of local anesthetic agents to the nerve pathways involved in the conduction of pain seems more physiologic. Only an occasional patient will have both functional and organic reasons for pain with difficulty in separating these possible etiologic factors. In such patients, differential epidural block has proved helpful in evaluating the patient for cordotomy.

RENAL FAILURE FOLLOWING HYPOVOLEMIA: ITS RELATION TO THERAPY *

JERRY A. STIRMAN, M.D., AND BEN J. WILSON, M.D.

With the technical assistance of KEN DUBOIS, M.A.

Dallas, Texas

Acute renal failure is usually precipitated by such events as an incompatible blood transfusion reaction, prolonged shock, septicemia, multiple renal infarcts and other recognized etiologic factors. Some persons develop acute renal failure unattended by the usual precipitating events. Retrospective scrutiny of such a group of patients has delineated a possible etiologic set of circumstances. In these patients whole blood was given in anticipation of blood loss or was given to treat minimal hypotension. In every instance there was a pre-existent extracellular fluid volume deficit or there was the loss of extracellular fluid alone or with whole blood during a surgical operation or after an injury.

The following experiments were undertaken to study in the dog the effects on renal function of the infusion of compatible whole blood after the production of an acute extracellular fluid volume deficiency.

METHODS

A comparison was made of the effects on renal function of two methods of treatment of an acute extracellular fluid volume deficit. A balanced salt solution and whole blood were the two test solutions. Each animal served as its own control and was subjected to two identical depletion experiments on separate days. After one of these depletion procedures, an infusion of Coomb's cross matched whole blood was given; after the other, a balanced salt solution was administered. Random selection determined whether one form of treatment was used in the first or second experiment.

Control determinations of the sucrose extracellular fluid space, the glomerular filtration rate (from Newman's formula of slope times volume and from the conventional urinary excretion of sucrose), blood pressure, hematocrit and plasma urea and sodium concentrations were performed. Repeat studies were done after the depletion procedure and after treatment. Control studies were performed approximately one week prior to depletion. Postdepletion and posttreatment determinations were accomplished on the same day. The second depletion experiment was done about one week after the first study.

The extracellular fluid volume depletion was produced by the 2-hr. intraperitoneal dialysis of 150 ml./kg. of 10 per cent glucose in distilled water. Treatment consisted of the intravenous infusion of 75 ml./kg. of one of the test solutions. Thirty-five mg. per cent of urea was added to the balanced salt solution to obviate dilutional effects of the plasma urea concentration. The whole blood was drawn under sterile conditions just prior to use, and adjustment of the hematocrit to 40 per cent was made. Compatibility of the whole blood was tested utilizing Coomb's antisera in the cross matching technique.

The sucrose extracellular fluid space was calculated by the total load formula using injection times of less than 10 sec. Sucrose was determined by the anthrone procedure.[8]

Urea was measured by the Van Slyke aeration method.[7] Plasma sodium concentration was determined by the flame photometer. The experiments were designed to allow pairing of data. The changes induced in the same animal were compared using the difference in the results of the two therapeutic regimes. The mean difference should not differ significantly from zero providing the two treatment schedules induced the same degree of change. This hypothesis was tested by the *t* test. The same reasoning and test were also applied to the two depletion experiments in the same animal.

From the Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

* This research was supported in part by the United States Air Force under Contract No. AF 41 (657)-90, monitored by the School of Aviation Medicine, USAF, Randolph Air Force Base, Texas.

RESULTS

The effects of acute extraction of extracellular fluid were a rise in hematocrit of 60 per cent, a fall in the extracellular fluid volume of 50 per cent, a decrease of the glomerular filtration rate of 80 per cent and a decline of the serum sodium of about 10 per cent. There was a slight fall in the plasma urea.

Ten animals have been studied; each one received both test solutions, so a total of 20 experiments have been completed and each animal is its own control. Six other dogs were subjected to extracellular fluid depletion and were given no treatment.

Table 1 presents the changes in the extracellular fluid volume (sucrose space) attending the depletion procedure and the two treatments employed. No statistical difference was found between the two depletion states in the same animals prior to therapy. Treatment with equal volumes of saline solution and whole blood produced significantly different values; the greater expansion was yielded by the infusion of the lactate Ringer's solution. This disparity was probably the result of the measuring technique using sucrose which is not distributed into the red blood cells; consequently, the volume of infused red cells is properly not included as extracellular space.

TABLE 1

Posttreatment extracellular fluid volume (liters)

Dog	Salt Therapy			Blood Therapy		
	After depletion	After therapy	Increment	After depletion	After therapy	Increment
15 (S)	1.903	4.207	2.304	1.831	2.643	0.812
25 (B)	1.517	3.614	2.097	1.334	1.773	0.439
26 (S)	1.847	4.100	2.253	1.656	2.002	0.346
29 (S)	1.423	3.043	1.620	1.531	2.331	0.800
14 (B)	1.745	3.814	2.069	1.863	3.109	1.246
13 (S)	0.880	2.510	1.630	1.094	2.338	1.244
11 (S)	1.320	3.249	1.929	1.186	2.892	1.706
9 (B)	1.369	3.987	2.618	1.753	3.689	1.936
2 (B)	1.418	3.416	1.998	1.237	2.415	1.178
1 (B)	1.713	3.566	1.853	1.730	3.556	1.826

Difference between postdepletion (before salt) and postdepletion (before blood) values—mean difference, 0.008; standard error, 0.062; t, 0.130; p, 0.85 (not significant).

Difference between increment due to salt therapy and due to blood therapy—mean difference, 0.884; standard error, 0.197; t, 4.48; p, 0.001 (significant).

TABLE 2

Posttreatment glomerular filtration rate (milliliters/minute)

Dog	Salt Therapy			Blood Therapy		
	After depletion	After therapy	Increment	After depletion	After therapy	Increment
15	10.49	42.63	32.14	10.76	21.48	10.72
25	11.04	28.17	17.13	3.26	11.52	8.26
26	12.07	53.87	41.80	11.95	10.33	−1.62
29	11.32	75.23	63.91	10.22	42.96	32.74
14	11.84	67.75	55.91	6.57	54.11	47.54
13	8.36	40.25	31.89	8.37	21.74	13.37
11	9.97	49.23	39.26	11.79	33.90	22.11
9	11.78	94.46	82.68	11.15	40.01	28.86
2	9.74	43.37	33.63	8.94	24.09	15.15
1	16.08	40.36	24.28	14.71	26.57	11.86

Difference between postdepletion (before salt) and postdepletion (before blood) values—mean difference, 1.501; standard error, 0.901; t, 1.66; p, 0.15 (not significant).

Difference between increment due to salt therapy and due to blood therapy—mean difference, 23.36; standard error, 4.76; t, 4.91; p, 0.001 (significant).

The glomerular filtration rate falls to equally low levels in the paired groups following intraperitoneal dialysis; yet the infusion of the crystalloid solution restored the glomerular filtration rate to a significantly greater degree than did the infusion of compatible whole blood (table 2).

The mean difference in the quantity of fluid and sodium removed by the peritoneal dialysis procedure prior to the employ of each treatment was not significantly different from zero, attesting to the similarity of the depleted state in the same animal prior to each type of replacement solution (table 3).

In table 4 is noted the equal restoration of blood pressure by either modality of treatment.

The hematocrit values after depletion were elevated equally in both groups. The hematocrit (table 5) levels are promptly restored to normal by the infusion of a balanced salt solution. However, after the infusion of whole blood which had a lower hematocrit than the recipient's blood, the hematocrit rose further.

After depletion, but prior to therapy, the dogs

TABLE 3

Peritoneal dialysate. Excess volume removed (milliliters); total sodium removed (milliequivalents)

Dog	Before Salt Therapy		Before Blood Therapy	
	Excess volume	Sodium	Excess volume	Sodium
15	730	174	485	158
25	350	145	555	141
26	400	168	660	200
29	570	152	605	174
14	630	171	450	122
13	415	112	300	105
11	660	163	500	141
9	730	158	785	173
2	480	118	655	110
1	790	215	625	180

Difference in excess volume removed before salt therapy and before blood therapy—mean difference, 13.5; standard error, 57.0; t, 0.237; p, 0.80 (not significant).

Difference in total sodium removed before salt therapy and before blood therapy—mean difference, 6.8; standard error, 7.9; t, 0.860; p, 0.45 (not significant).

TABLE 4

Blood pressure (millimeters of mercury)

Dog	Salt Therapy			Blood Therapy		
	After depletion	After therapy	Increment	After depletion	After therapy	Increment
15	69	105	36	79	105	26
25	85	130	45	75	125	50
26	105	135	30	110	135	25
29	95	150	55	112	130	18
14	75	120	45	74	145	71
13	62	130	68	69	120	51
11	69	113	44	83	115	32
9	80	143	63	75	125	50
2	77	96	19	90	120	30
1	80	120	40	80	106	26

Differences in blood pressure depression before salt therapy and before blood therapy—mean difference, 3.8; standard error, 2.91; t, 1.31; p, 0.20 (not significant).

Differences in changes in blood pressure due to salt therapy and blood therapy—mean difference, 6.6; standard error, 5.47; t, 1.21; p, 0.25 (not significant).

TABLE 5

Hematocrit (per cent)

Dog	Salt Therapy			Blood Therapy		
	After depletion	After therapy	Change	After depletion	After therapy	Change
15	49.8	36.2	−13.6	47.5	69.0	21.5
25	66.0	52.0	−14.0	55.5	68.0	12.5
26	47.5	35.0	−12.0	44.0	50.0	6.0
29	66.2	44.5	−21.7	55.5	52.0	−3.5
14	62.2	40.0	−22.2	56.0	58.0	2.0
13	79.0	61.0	−18.0	63.0	65.2	2.2
11	64.0	47.0	−17.0	73.0	74.0	1.0
9	62.0	37.0	−25.0	56.5	66.5	10.0
2	53.0	40.0	−13.0	72.0	62.5	−9.5
1	67.0	45.0	−22.0	62.0	58.0	−4.0

Difference in hematocrit before salt therapy and before blood therapy—mean difference, 3.17; standard error, 3.21; t, 0.998; p, 0.35 (not significant).

Difference in changes in hematocrit due to salt therapy and due to blood therapy—mean difference, 21.67; standard error, 2.93; t, 7.30; p, 0.001 (significant).

TABLE 6

Urine flow rates (milliliters per minute)

Difference between urine flow rates after salt therapy and after blood therapy*

Dog	After Blood Therapy	After Salt Therapy
15	0.138	0.626
25	0.037	0.272
26	0.000	0.314
29	0.257	0.569
14	0.532	0.852
13	0.250	0.360
11	0.201	1.856
9	0.164	0.531
2	0.307	0.417
1		0.452

* Mean difference, 0.435; standard error, 0.158; t, 2.75; p, 0.025 (significant).

were anuric. After treatment urine flow increased; the balanced salt solution was distinctly superior to whole blood in promoting urine flow (table 6).

Table 7 depicts the changes in blood urea accompanying therapy. No significant difference was noted prior to therapy or immediately after therapy with either test solution. Twenty-four hours later, however, the blood urea was signifi-

TABLE 7

Blood urea nitrogen (milligrams per cent)

Dog	Salt Therapy				Blood Therapy			
	After depletion	After treatment	After 24 hours	Change 24 hours after treatment	After depletion	After treatment	After 24 hours	Change 24 hours after treatment
15	58.0	58.8	52.2	−6.6	33.8	38.2	45.4	7.2
25	33.8	43.2	20.6	−22.6	15.6	24.0	37.6	13.6
26	25.6	29.6	14.8	−14.8	22.0	26.8	44.6	18.2
29	11.4	20.2	17.0	−3.2	31.0	38.6	27.2	−11.4
14	25.4	34.6	22.2	−12.4	31.2	35.0	24.6	−10.4
13	29.2	28.0	24.6	−3.4	29.2	31.6	43.2	11.6
11	35.2	35.8	24.8	−11.0	30.0	37.0	26 8	−10.2
9	11.6	20.6	12.0	−8.6	15.2	24.8	28.0	4.0
2	45.6	47.6	30.2	−17.4	31.0	38.0	113.0	75.0
1	29.8	48.6	33.0	−15.6	18.4	25.4	44.4	19.0

Differences between post depletion (before salt) and post depletion (before blood)—mean difference, 4.82; standard error, 4.08; t, 1.18; p, 0.30 (not significant).

Differences between changes due to salt therapy and blood therapy—mean difference, 23.26; standard error, 9.04; t, 2.57; p, 0.025 (significant).

TABLE 8

Plasma sodium concentration (milliequivalents per liter)

Dog	Salt Therapy			Blood Therapy		
	After depletion	After treatment	Change	After depletion	After treatment	Change
15	136	145	9	138	148	10
25	130	140	10	143	150	7
26	126	142	16	150	152	2
29	130	146	16	121	150	29
14	134	145	11	140	153	13
13	151	163	12	133	142	9
11	125	137	12	145	157	12
9	139	152	12	147	150	3
2	142	145	3	113	124	11
1	125	135	10	117	132	15

Differences between plasma sodium concentration after depletion (before salt therapy) and after depletion (before blood therapy)—mean difference, 1.9; standard error, 5.6; t, 0.341; p, 0.75 (not significant).

Differences between increments due to salt therapy and to blood therapy—mean difference, 0.1; standard error, 2.47; t, 0.405; p, 0.65 (not significant).

cantly higher when the animal had been given whole blood than when the animal had been given a balanced salt solution.

No significant difference was found in the changes in serum sodium concentration prior to therapy or after the infusion of the test solutions (table 8).

Six animals were subjected to the standardized depletion procedure and no replacement solution was given. All animals died within 24 hr. When treatment was given there were no immediate deaths, but 3 animals died within a week subsequent to the infusion of whole blood. All dogs receiving lactate Ringer's solution survived.

DISCUSSION

The shock state attending the acute extraction of extracellular fluid is characterized by hypotension, anuria and death if no treatment is given. Either type of infusate (salt solution or whole blood) improved the mortality rate, but equal improvement in renal function was not obtained.

The results of this study demonstrate that the infusion of whole blood to combat the hypotension attending an acute extracellular fluid volume depletion is less effective in restoring renal function than is the infusion of an equal volume of lactate Ringer's solution. The immediate restoration of glomerular filtration rate and urine flow with salt solutions was distinctly superior to that following whole blood. Some impairment in function lasts for at least 24 hr. after whole blood treatment is attested to by the continued elevation of blood urea in 7 of 10 dogs, and by persistent severe oliguria in 2 of the dogs receiving whole blood. That the difference in blood urea concentration might have been a function of infused load was obviated by the addition of urea to the crystalloid solution, so the infused loads of urea in the whole blood and into salt solutions were essentially equal. That any significant mass of red cell globin was metabolized and converted to urea in 24 hours is unlikely in the light of known red cell survival time, the absence of hemolysis and the slow rate of entry of globin into the protein metabolic pool.

Recently reported work of Pappenheimer and Kinter[4] suggests a possible mechanism to explain the findings of these experiments. According to the cell separation theory of renal hemodynamics, autoregulation of renal function is accomplished by plasma skimming. The two major factors which govern efficiency of plasma skimming are the perfusion pressure and the hematocrit.[2-4] When a dog is rapidly depleted of extracellular

fluid, the arterial blood is of high hematocrit and under a low perfusion pressure, eventuating in a decrease in plasma skimming and a fall in glomerular filtration rate. In the present series, restoration of perfusion pressure was effected by either the infusion of whole blood or a balanced salt solution. However, there was not equal improvement in the glomerular filtration rate. This may be explained in part by the difference in the perfusing hematocrit. Correction of the hematocrit level simultaneously with the correction of the perfusion pressure restores the normal distribution of functioning glomeruli from proximal to distal glomeruli, and an over-all improvement in the glomerular filtration rate to normal. Further the conjecture is made that when the hematocrit level of the blood perfusing to kidney remains high, the distributional patterns of functional glomeruli are not restored, and fewer of the distal glomeruli receive blood with a hematocrit sufficiently low to restablish a normal filtration rate. It would appear that despite the restoration of the blood pressure in the dogs by whole blood therapy renal dysfunction continues. If this dysfunction persists, it is thought likely that acute renal failure may occur.

An alternate explanation of these results is suggested by the work of Spencer.[5, 6] Studying the acute hypervolemic polycythemic state, he found that in the normal dog the glomerular filtration rate was maintained in the face of increased viscosity by renal vasodilation. When renal vasodilation did not occur (during anesthesia and following renal denervation), marked falls in the glomeruli filtration rate attended increments in viscosity. In the experiments reported in this paper it is felt that renal vasodilation was prevented by the preceding hypovolemic shock, in which renal vasoconstriction is known to occur and to persist for a variable time after restoraton of the lost volume.[1] That renal vasoconstriction, high viscosity of blood, abnormal patterns of plasma skimming and low perfusion pressures may all participate in the production of functional failure of the kidney during and following traumatic shock seems likely.

There are several clinical states which mimic the present experimental conditions. Chief among these are the shock attending thermal injury, chemical or bacterial peritonitis and the crush syndrome. Acute renal failure or at least temporary renal dysfunction is a common complicating factor in the management of these patients. Experience has indicated that the treatment of these clinical states with whole blood alone frequently fails to promote adequate renal function. The results found in this controlled study tend to support the clinical observations and to confirm the fact that the treatment of shock attending an acute extracellular fluid volume deficit should not be whole blood.

REFERENCES

1. Corcoran, A. C., and Page, I. H.: Effects of hypotension due to hemorrhage and of blood transfusion on renal function in dogs. J. Exper. Med., *78:* 205, 1943.
2. Kinter, W. B., and Pappenheimer, J. R.: Renal extraction of PAH and of Diodrast—I^{131} as a function of arterial red cell concentration. Am. J. Physiol., *185:* 391, 1956.
3. Kinter, W. B., and Pappenheimer, J. R.: Role of red blood corpuscles in regulation of renal blood flow and glomerular filtration rate. Am. J. Physiol., *185:* 399, 1956.
4. Pappenheimer, J. R., and Kinter, W. B.: Hematocrit ratio of blood within mammalian kidney and its significance for renal hemodynamics. Am. J. Physiol., *185:* 377, 1956.
5. Spencer, M. P.: Renal hemodynamics in experimental polycythemia. Am. J. Physiol., *165:* 399, 1951.
6. Spencer, M. P.: Acute effects of moderate increases in hematocrit on the hemodynamics of the normal and denervated kidney. Am. J. Physiol., *178:* 462, 1954.
7. Todd, J. C., and Sanford, A. H.: *Clinical Diagnosis by Laboratory Methods*, Ed. 10. W. B. Saunders Company, Philadelphia, 1943.
8. Young, M. K., Jr., and Prudden, J. F.: The simultaneous determination of sucrose and insulin in biologic fluids. J. Lab. & Clin. Med., *44:* 160, 1954.

ARTHROPLASTY OF THE ANKYLOSED TEMPOROMANDIBULAR JOINT

ROBERT V. WALKER, D.D.S.

Dallas, Texas

Ankylosis of any joint is associated with considerable inconvenience and crippling. The temporomandibular joint is no different, except the type of inconvenience and incapacity produced. Normal function of the temporomandibular joint is an important factor in speech and eating, and the form of the mandible is important in determining symmetry and size relation harmony of the face and jaws. Should an ankylosis of the temporomandibular joint occur during the growth years of childhood there results a gross distortion of the lower jaw and face of the involved side. This can and frequently does lead to psychologic trauma to the patient, producing a psychic overlay to the deformity which can be of more significance than the organic affliction. Apart from the direct limitation of normal jaw, movement and alteration of facial form, ankylosis of the mandibular joints disheartens the patient for the practice of adequate oral hygiene and the performance of routine dental procedures, thus indirectly leading to advanced and extensive dental caries, with ensuing pain, and abscess formation. For these and perhaps many additional reasons any procedure which can rectify or improve the patient's lot must receive careful and considerable thought.

CLINICAL APPEARANCE OF THE PATIENT

The time at which an ankylosis occurs is a predominant factor in the production of symmetry or asymmetry of a patient's face and jaws. Should an ankylosis occur during the period of growth and development, which results in destruction of the growth potential of the condyle, there can be no result other than a distortion of the facial features. There are numerous growth areas about the mandible, notably the condyle itself, the posterior border of the mandibular ramus, and along the alveolar process, but there can be no question that the condyle is the most important and most active growth site of the mandible.[13] Indeed, according to studies completed by Sarnat,[18] mandibular growth can be considered to be a leading factor of facial growth.

This has been borne out in the examination of patients referred with a history of an ankylosis that occurred during the growth years. If the ankylosis is unilateral the patient presents clinically with a markedly asymmetrical face, there being an obvious deviation of the mandible to the ankylosed side (fig. 2*A*). In spite of altered growth on the involved side, the opposite jaw develops somewhat normally and appears to grow across the midline to meet the shortened side. The "normal" side of the face, therefore, appears flatter, with a longer lower jaw, and is considerably less full or rounded than the retarded side.

In profile the angle of the mandible on the ankylosed side is nearer the lower lobe of the ear and zygomatic arch than on the normal side, this representing a marked shortening of the ramus (fig. 2*B*). From the angle to the most advanced point of the symphysis of the mandible the linear length on the growth embarrassed side is significantly shorter than on the opposite side. The zygoma usually is somewhat flatter in comparison to its contralateral mate. Intraorally there is visible underdevelopment of the maxilla on the ankylosed side, particularly along the alveolar process, and perhaps there are even partially submerged or unerupted teeth. Should the ankylosis be bilateral during the growth years the result is a symmetrical alteration as described above. The most prominent distortion would be the production of a true micrognathic individual.

Ankyloses, either unilateral or bilateral, occurring after the growth years are not productive of asymmetrical facial and jaw changes other than those associated with the form of the articulation itself (fig. 7*A*, *B*).

From the Division of Oral Surgery, Department of Surgery, University of Texas, Southwestern Medical School, Dallas, Texas.

The fine art work and reproduction of picture prints by Mr. Lewis Waters and Miss Patti O'Neill of the Department of Medical Art, The University of Texas Southwestern Medical School, is gratefully acknowledged.

CLINICAL DIAGNOSIS OF TEMPORAMANDIBULAR JOINT ANKYLOSIS

The clinical diagnosis of temporomandibular joint ankylosis presents little difficulty. Unyielding and rigid immobilization is rare, for even in the complete and solid fusion of bilateral ankylosed joints there is enough elasticity in such a cantilevered bone that as much as 1 to 2 mm. opening between the incisal edges of the teeth can be produced by the patient. Differentiation between intra- and extra-articular ankyloses may be ascertained by asking the patient to protrude his jaw. Extra-articular lesions which prevent jaw opening usually do not involve the ability of the patient to thrust his jaw forward. It will be evident that the jaw moves forward regardless of whether the extra-articular lesion is unilateral or bilateral. Intra-articular ankylosis, fibrous or bony, of the temporomandibular joint may present single or multiple clinical features which are significant. The temporomandibular articulation in the normal individual is peculiar to other joints in that an interposing intra-articular disk separates the articular confines into an upper and a lower compartment, the upper compartment housing the sliding movements identified with this joint and the lower compartment functioning as a true hinge joint. Sicher[20] thus classifies the temporomandibular joint as a hinge joint with a movable socket. With such an articular arrangement the patient enjoys hinge and excursive movements of lateral and protrusive positions identified as a part of the normal function of the jaw. Either the upper or lower compartment, singularly or both at the same time, may be involved in an ankylosis. There are characteristic clinical features which aid in distinguishing which compartment is involved with the lesion, or if the entire joint is involved. If a unilateral upper compartment is involved,

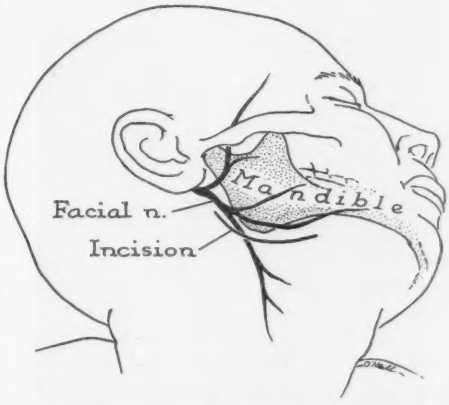

FIG. 1. The line of incision, submandibular route, made from a point slightly posterior and superior to the angle of the mandible is brought forward paralleling and 1 cm. below the inferior border of the mandible. Positioning is done by placing a sheet folded to four thicknesses beneath the patient's shoulders. The patient's head is turned to the opposite side and the neck flexed in hyperextension so that the angle of the mandibl is outlined in visible relief and easily accessiblee

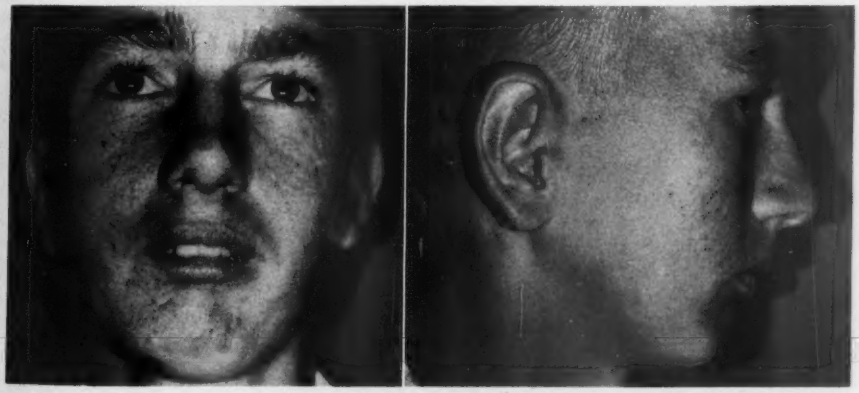

FIG. 2. (*A, left*) Eighteen-year-old boy with ankylosis of right temporomandibular joint of 13 years' duration. Asymmetry of face due to deviation of left mandible across mid-line to involved side. (*B, right*) Ankylosis of right side demonstrating shortness of ramus height.

the patient is able to enjoy conventional rotary movements of the mandible, but in the protrusive excursion there will be marked deviation to the involved side. With bilateral upper compartment involvement hinge opening is allowable, but no protrusive movement at all is possible. If a unilateral or bilateral lower compartment is involved, the patient will be able to thrust his jaw forward, but here the rotary or hinge movements become labored or at times impossible. The uninvolved temporomandibular articulation of a unilateral intra-articular ankylosis remains normal, and normal function may be expected to return once relief is gained on the ankylosed side.

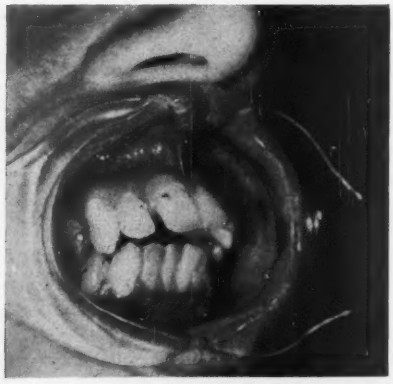

FIG. 3. Occlusion of teeth; no opening possible

RADIOGRAPHIC AID IN DIAGNOSIS AND TREATMENT PLAN

Radiographic examination of the ankylosed temporomandibular articulation should offer confirmation of the clinical diagnosis. Standard posterior-anterior and profile projections of the condylar areas lend substantial aid in planning the site of joint reconstruction and the technical difficulties likely to be encountered in sectioning in such areas. Overgrowths, thickening, and density of the bone in the area are determinable by these radiographs (fig. 4*A*, *B*). However, laminograms in the lateral profile and posterior-anterior projections are probably of the greatest value in determining the extent of the ankylosis and are considered by Georgiade and associates[7] "the *sine qua non* in diagnosing any bony ankylosis of the temporomandibular joint." This technique of radiography is of especial merit in demonstrating the condylar area without the usual superimposi-

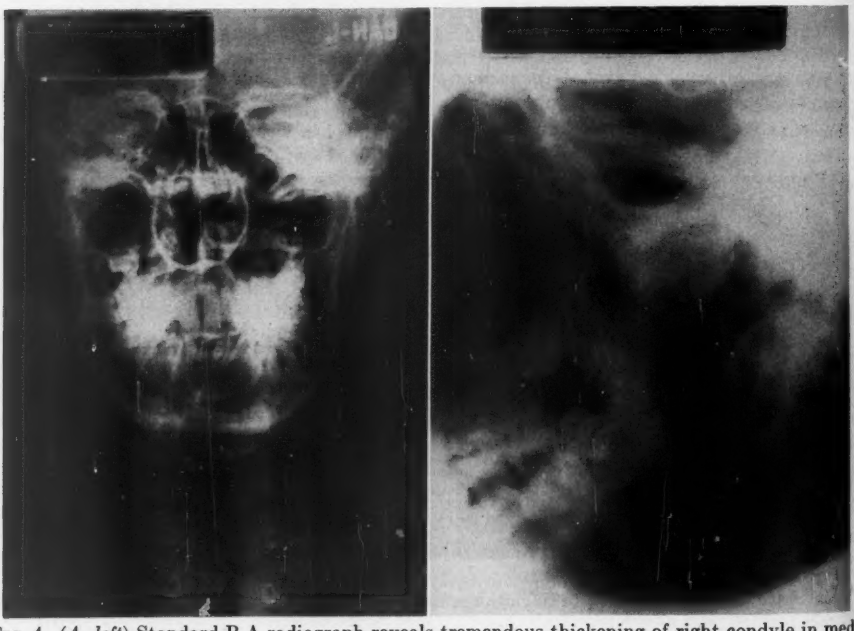

FIG. 4. (*A*, *left*) Standard P-A radiograph reveals tremendous thickening of right condyle in mediolateral dimension. (*B*, *right*) Lateral radiograph demonstrating sclerotic articular area with overgrowth in antero-posterior dimension.

tion of the numerous cranial and facial osseous structures (fig. 8*A*, *B* and 9).

PROBLEMS AND THEIR MANAGEMENT IN TEMPOROMANDIBULAR ARTHROPLASTY

The problems involved in the treatment of a temporomandibular ankylosis are: the selection of a suitable and safe approach to the articular area; the provision of adequate exposure to allow precise and satisfactory sectioning of bone; the determination of the exact area of bone that should be removed; the maintenance of normal ramus height and concomitantly the normal occlusion of the teeth; the restoration of function of the jaw to as near normal as possible; the prevention of the distal and proximal segments of the bone sectioned becoming reapproximated and ankylosis recurring.

Surgery in and about the temporomandibular joint remained unattended for many years because of the very inaccessability of the relatively superficial articular area. The area is traversed by anatomic entities of major surgical importance, the most prominent of which are the parotid gland, the facial nerve, the posterior facial vein, and the external carotid artery as it branches into its terminal arborizations, the superficial temporal and internal maxillary arteries. The possibility of inadvertant mutilation or transection of any of these structures frequently was enough to deter planned surgical maneuvers at this area.

With the advent of more refined surgical techniques the temporomandibular articular area is now considered not quite so inaccessible nor

FIG. 5. Postoperative functional result and degree of incisal opening.

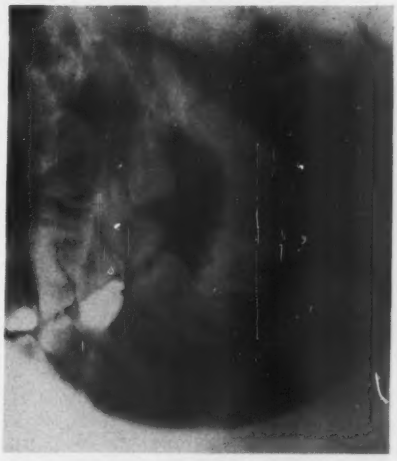

FIG. 6. Postoperative lateral radiograph demonstrating position of ostectomy. Cartilage not radiologically visible.

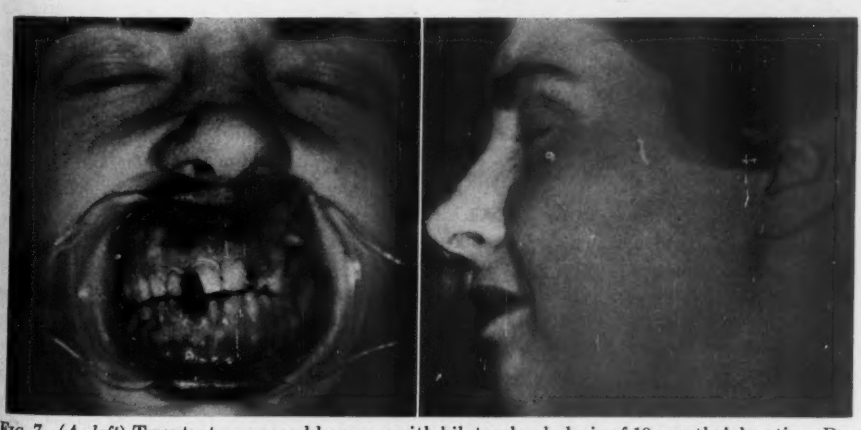

FIG. 7. (*A*, *left*) Twenty-two-year-old woman with bilateral ankylosis of 10 months' duration. Degree of incisal opening. (*B*, *right*) Left profile demonstrating normal symmetry of face in ankylosis of an adult.

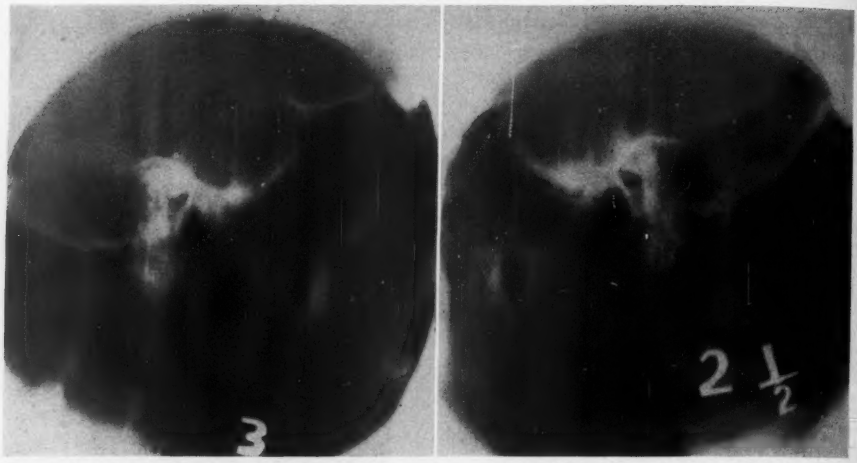

FIG. 8. (*A, left*) Laminagram of left articular area revealing eburnation of bone and obliteration of joint space. (*B, right*) Laminagram of right articular area. Ankylosis of such short duration that overgrowth has not yet occurred.

FIG. 9. P-A laminagram

formidable. Either the preauricular approach, first advocated by Verneuil,[21] or the submandibular approach described by Risdon[17] offer adequate safety and access to the area, with proponents of each technique firmly convinced that their approach tenders greater advantages over the other. The approach advocated at this institution is the submandibular route (fig. 1). It is felt that there is less danger of doing major damage to the trunk of the facial nerve, while it is a relatively simple matter to isolate the marginal mandibular and cervical branches of this motor nerve during the early dissection for controlled and protected retraction (fig. 12*C*). Also by this approach it is possible to visibly survey the entire antero-posterior width of the ramus, the coronoid process and the morphologically altered condylar and sigmoid notch area (fig. 11). It appears that this visual survey is of particular advantage in determining the optimal position for placement of cuts to section the mandible below the ankylosed area. The greatly thickened condylar mass and neck of an ankylosis of several years' duration frequently dictates that sectioning be done at a lower and technically more accessible area than an intra-articular ankylosis which is only a few months old. This is of some importance in guarding your cuts proceeding medial-wise, for when the condylar mass is greatly thickened in an antero-posterior direction you can be assured it is no less thickened in a medio-lateral dimension. With such alteration in the whole vicinity of the articular area there can be no precise prediction of the exact devious routes the internal maxillary artery, the inferior alveolar vessels and even the masseteric artery might assume. Consideration for adequate protection of these vessels is a requisite for a safe, orderly and uneventful sectioning. There has been little mentioned regarding the masseteric artery in previous reports, but it can be a particularly troublesome factor.

Normally the masseteric artery leaves the in-

ternal maxillary artery on its lateral surface and passes laterally through the sigmoid notch to the masseter muscle.[20] In an ankylosis, as the condyle thickens in an antero-posterior plane, the interval of space between the condyle and coronoid process, the sigmoid notch, is reduced proportionately (fig. 4*B*) thereby confining the masseteric artery to a small and inaccessible area should transection occur.

Identification, isolation and retraction of the parotid gland in the superior flap created has not proved onerous from the submandibular approach. However, for those who envision some difficulty in management of the gland there is a particularly appealing report by Forrest and Robinson,[6] who advocate the use of *in vivo* staining of parotid gland tissue by the injection of sterile 1 per cent aqueous methylene blue through Stensen's duct just prior to surgery in and about this gland. It is claimed that such staining vividly outlines all portions of the gland, providing easy identification in contrast to surrounding tissue. The amount of methylene blue recommended is well below the aggregate necessary for the production of undesirable side effects.

The consideration of the optimal position for the arthroplasty to be created is obviously of great import. From a physiologic standpoint there is no way to restore a joint once ankylosed to absolute efficiency and normal function. However, the compromise to be gained must be within a range that is acceptable to the patient and functionally adaptable to his para-articular tissue and musculature. As mentioned previously, the articulation is comprised of an upper and a lower compartment separated by an intra-articular disk, which allows hinge and sliding excursive movements in the lateral and protrusive positions. Such a complicated and precise function cannot be predicted following an arthroplasty, but such a situation is not entirely without possibility considering the adaptability of the musculature with training.

Ideally the arthroplasty should be performed at the articular area, but there are important reasons why this is not feasible nor possible. Ankyloses of long standing, as mentioned previously, produce gross alterations and there is little morphologically to identify what is condyle, previous joint space, or articular fossa of the temporal bone. It is not inconceivable that too forceful chiseling or injudicious burring attempts to produce a true disarticulation at the previous joint space could result in a linear fracture of the middle cranial fossa or perforation with a bur. Just as importantly, the morbid overgrowth of bone seen in such situations is markedly sclerotic and eburnated (fig. 4*A*, *B*) constituting an extremely poor bed for the restoration of a workable articulation.

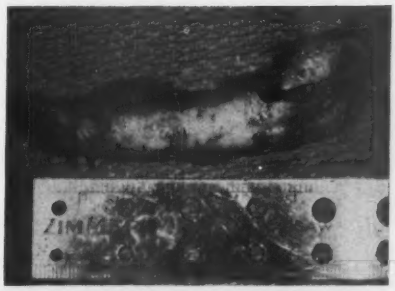

FIG. 10. Substantial piece of cartilage approximately 6.5 cm. in length and 1 cm. in thickness obtained from 5th rib for reconstruction of both joints.

FIG. 11. Visible survey of left ramus, articular area, sigmoid notch, and coronoid process from submandibular approach.

As stated by Boyd,[3] "this type of osseous structure bears the same relationship to normal bone that fibrous scar tissue bears to normal soft tissue." Technically the enlarged articular mass is difficult to cut through and at the same time offer adequate protection to important anatomic entities on the medial surface of the ramus. In sectioning at an obviously thickened area there will be greater surfaces of raw bone exposed which ideally should be covered. Adhering to these observations, the ostectomy site usually selected is from the deepest point of the sigmoid notch extending to the posterior border of the mandible (fig. 11). The ostectomy site is widened in an interior direction with the section of bone removed varying between 0.5 and 1.0 cm.

FIG. 12. (*A, upper*) Bone excised from sigmoid notch to posterior border of ramus. Traction at angle gained by stainless steel wire threaded through hole drilled at angle. (*B, middle*) Cartilage carved to overfill and interpose at ostectomy site. (*C, lower*) Isolation of marginal mandibular and cervical brances of the facial nerve for controlled and protected retraction.

Should the sigmoid notch be completely obliterated by exuberant overgrowth of the condylar mass, the ostectomized area should be extended from the anterior to the posterior borders of the mandible midway between the estimated position of the mandibular foramen and what would normally be the depth of the sigmoid notch. Creation of the cuts is accomplished using a no. 703 crosscut carbide fissure bur run under a constant stream of cold normal saline solution. The control obtainable with a dental straight handpiece and bur affords precision in placement and depth of the cuts not offered by other means. Once a through-and-through section is obtained, widening of the ostectomy site may be accomplished under direct visualization by use of conventional rongeurs or Kerrison back-biting forceps. Adequate vision is obtained by drawing

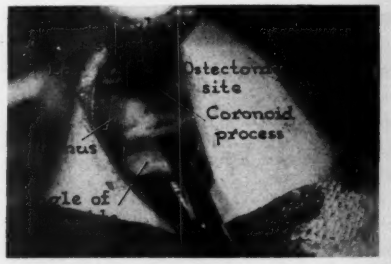

FIG. 13. Ostectomy of right subcondylar area completed. Traction at angle obtained with conventional bone forceps.

FIG. 14. Interposition of cartilage carved to completely cover raw surfaces of bone.

the ramus inferiorly with either a bone grasping forcep (fig. 13) or by drilling a hole through the bone near the angle of the jaw and threading a heavy gauge stainless steel wire through the hole, the wire then acting as a traction device (fig. 12*A*).

Even the remote possibility of re-ankylosis occurring following restoration of jaw function requires every consideration to prevent such a failure of the procedure. Satisfactory function of a jaw is assured even without the interpositioning of tissue at the ostectomy site, but it has been proved clinically that the placement of an interposing substance materially reduces the likelihood of a recurrent ankylosis.

The mechanics of mandibular function have been likened to a class three lever.[10, 11] In the normal circumstance the condyles act as the fulcrum in such a mechanical comparison, the major muscles of mastication, the masseters, internal pterygoids and temporalis acting as the major force, and the result being the obvious gross movements of the jaw anterior to the major muscles of the mastication. This observation is a fair description, for when the condyles are removed the jaw is immediately changed to a lever of the first class. No condyles being present, the fulcrum is now transferred to the most posterior occluding molar teeth. This transfer of the fulcrum to the immediate point between the major forces and the resultant gross actions of the anterior mandible justifies the classification as a class one lever. However, such a situation predisposes to a subsequent open bite at the incisor area. With the continuous upward pull of the masseters, internal pterygoids, and temporalis muscles, the ramus is drawn slowly into the area formerly occupied by the condyles. With the last occluding molar teeth functioning as a fulcrum such action produces an opening between the teeth at the incisor area comparable to and usually considerably wider than the space closed at the condylar areas. This situation is hardly compatible with normal masticatory function or productive of a physiognomy which is appealing to the patient. For this reason there is ample cause for the placement of an interposing substance at the ostectomized site of a temporomandibular arthroplasty which offers the ability to maintain normal ramus height by the physical integrity of the interposed substance itself and allows the mandible to continue function as a class three lever.

FIG. 15. (*A, upper*) Postoperative functional result and degree of mouth opening. (*B, lower*) Left profile demonstrating placement of incision. Five days postoperative.

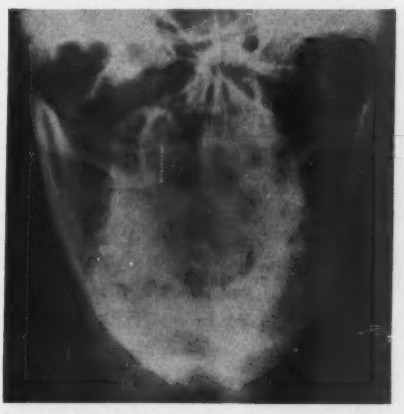

FIG. 16. P-A radiograph demonstrating ostectomy sites.

Various interposing substances, including muscle,[12] fascia lata,[9] dermis,[7] celluloid, tantalum foil,[5] gold plate,[16] pig bladder,[2] tantalum,[14] fat fascia,[13] temporal fascia,[2] bovine cartilage,[4] and autogenous cartilage[10, 11] have been used. Varying

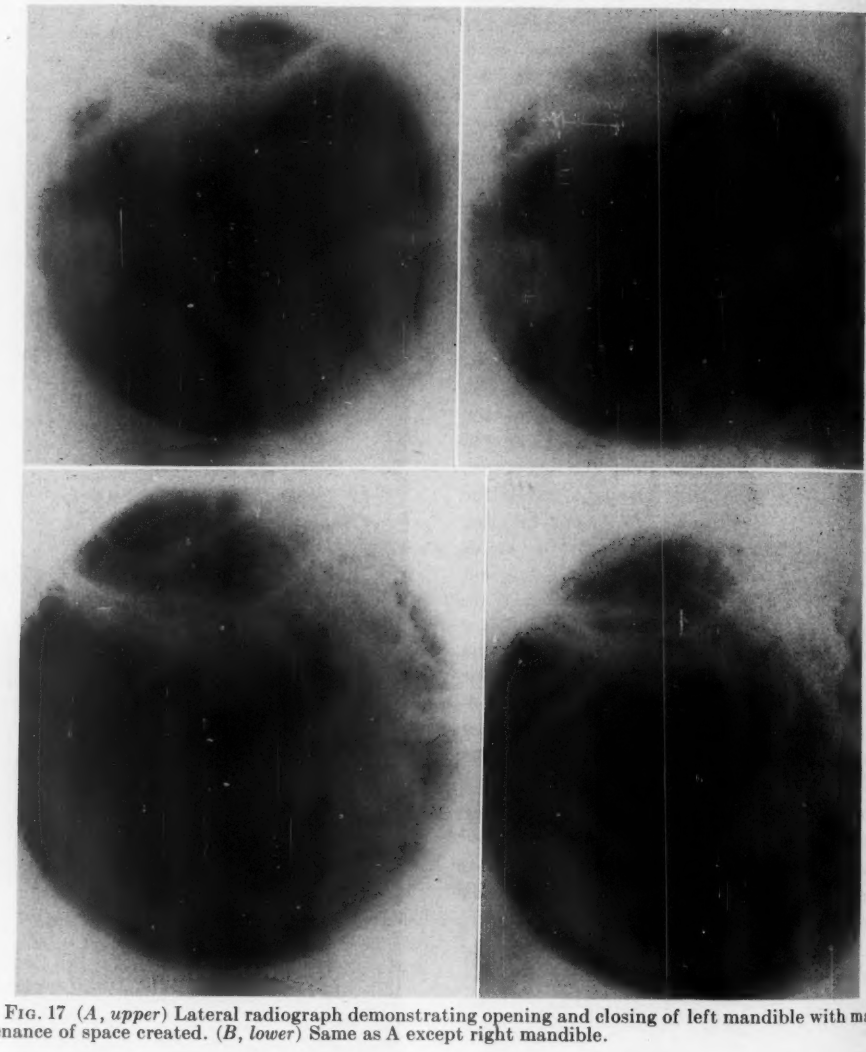

FIG. 17 (*A, upper*) Lateral radiograph demonstrating opening and closing of left mandible with maintenance of space created. (*B, lower*) Same as A except right mandible.

degrees of success have been attached to the use of all these substances.

The substance advocated for use at this institution is autogenous costal cartilage. This has proved practical from a standpoint of availability, being physiologically acceptable at the host area, and of such a physical makeup as to maintain the width created by ostectomy. Autogenous cartilage, a nonvascular tissue, has a tremendous propensity for survival regardless of where transplanted, provided it is completely surrounded by nourishing host tissue and not exposed.[15] It has been observed that chondrocytes of the donor cartilage survive when transplanted because of its unique nutritional setup not requiring immediate reanastomosis of a vascular and capillary bed. Diffusion of nutritive and waste metabolites about the chondrocytes through the gelled intercellular substances surrounding them supports cartilage survival when adequately bathed in tissue fluid of a host area.[8]

One of the prime attributes of cartilage is its

ability to withstand the trauma and stress of articulations as evidenced by its evolution as the tissue selected and adapted to line most contacting surfaces of movable joints. If a new joint is to be created, what finer interposing substance could be selected than one inherently adapted for such a locale? It can be carved with a scalpel to conform to the demands of the host area. Artistically the complete form of the articulation need not be recreated, but rather a realistic and complete covering of the raw surfaces of bone accomplished and a suitable thickness of cartilage provided to maintain the width of bone excised.

In ankylosis of a few years' duration fixation of the cartilage is not a problem, for when snugly seated in such a wide medio-lateral and antero-posterior plane between the raw surfaces of the ramus it shows no tendency to dislocate and is, in fact, firmly gripped in these areas as though in a vise, this purchase being kept taut by the natural upward pull of the masseter and internal pterygoid muscles. And in actuality in these older cases there is no plane, space or fossa into which such a sizable piece of cartilage could slip. In ankyloses of shorter duration, where hypertrophy of the articular components has not occurred and a normal sized condylar neck is found clinically, there does exist a problem of fixing the donor tissue. This can be solved by one of two methods. Either an excessively large piece of cartilage is carved to completely overfill the area, thereby preventing derangement by the mechanics involved in displacing an overly large substance into a much smaller space, or the cartilage transplant may be anchored securely with fascia lata to the stump of the ascending ramus of the mandible.

POSTOPERATIVE TREATMENT

Patients having a unilateral arthroplasty performed have been placed on an active regimen immediately after surgery. Movability has been somewhat limited immediately, but progresses rapidly following reduction of postoperative edema, muscle spasm and pain. A liquid diet is ordered for a couple of days, but the patient generally expresses such delight at the new found convenience of opening his mouth that a request for solid food is submitted. A soft diet is ordered for two weeks, after which time the patient is allowed a choice in the selection of his own diet as long as it is one not productive of excessive trauma in mastication. Chewing gum is encouraged because it offers a continuous source of exercise and reactivation of the muscles of mastication.

Patients who have had a bilateral arthroplasty performed have been immobilized for 5 days postoperatively. This has been done on the premise that immobilization aids in the thorough organization of a hematoma in and about the operative site, thereby helping to stabilize and fix the transplanted cartilage in position. Also, the early immobilization aids in the take of the transplant at the host site and insures its continued viability.

In retrospect it is felt that the period of jaw immobilization should be longer for a couple of reasons. The transplanted cartilage perhaps would benefit by a longer period of immobilization by becoming better acclimated in the host environment before being subjected to the demands of an articular area. A second and important reason is that the detached masseter muscle at the angle of the mandible requires more than a 4- or 5-day period at rest to insure substantial reattachment. Any real criticism of the submandibular approach to the temporomandibular articular area has to be directed partly at the necessity for detachment of this important muscle of mastication. In open reductions of condylar fracture from this approach there has been no need for consideration of this muscle detachment, for the period of immobilization required for bony union to occur at the neck of the condyle was more than enough to insure proper reattachment of the masseter at the angle of the jaw. There have been no subjective complaints registered by the patient because of this early mobilization, nor have there been latent muscular derangements observed by the examiner. The point may be academic, but it is considered worthy of mention because of possible neuromuscular imbalance which may occur—particularly in the unilateral case that is mobilized early.

DISCUSSION AND SUMMARY

Each surgeon performing temporomandibular joint arthroplasties makes a certain plea in support of the technique employed or the substance interposed between the raw surfaces of bone created by the ostectomy. There can be no real criticism of any procedure when the results are uniformly satisfying to the patient, are physi-

ologically tolerated, and meet the high standards of excellence demanded by those who accept the responsibility of treating such disabled patients.

The method presented represents the technique advocated at this institution. The aims to be gained in the reconstruction of a joint have been adhered to as closely as possible. The approach is simple and provides ample working space, yet avoids the larger vessels of the area. Sectioning of the bone is performed at an area that is as far as possible from the base of skull yet near enough to the normal joint that no major derangement of neuromuscular function and balance results.

Interposition and coverage with a substance at the ostectomy site prevents the formation of a continuous hematoma between the raw surfaces of bone created which is a precursor to recurrence of the ankylosis. The physical integrity of the selected substance, autogenous cartilage, is ideally suited to maintain ramus height and allow the fulcrum of the mandible to remain near its normal position, thus permitting the mandible to continue function with its most efficient classification, a lever of the third class. Unilateral or bilateral reconstruction as one operative procedure is justifiable and productive of satisfactory results without the necessity of the patient being subjected to two surgical episodes.

Of the patients operated there has been one rheumatoid arthritic on whom a bilateral reconstruction of ankylosed temporomandibular joints of 5 years' duration was performed. A fine clinical result was attained, with the patient enjoying an incisal opening of 28 mm. Seven months following the temporomandibular anthroplasties the patient died convalescing from another operative procedure which resulted in a wound infection, development of an agranulocytosis, overwhelming septicemia and death. At postmortem examination of the patient both complete reconstructed articular areas were removed through the middle cranial fossa. Examination of the articulations revealed that the cartilage had become firmly attached to the stump of the ramus in a manner comparable to an intra-articular disc, and the rotary movements permissible in such a joint reconstruction were taking place between the superior part of the cartilage and the condylar stump. Macroscopically the cartilage appeared as white and glistening and viable as on the day on which it was transplanted. Both joints have been submitted for sectioning and microscopic examination. A subsequent report of these findings will be submitted.

CONCLUSIONS

1. It is our opinion that the most acceptable substance for interposition between the raw surfaces of bone created by ostectomy at the site for joint reconstruction is autogenous cartilage. It possesses inherent qualities which warrant first rank consideration when contemplating use of an interposing substance.

2. Normal ramus height should be maintained and the mandible allowed to continue function as a lever of the third class by preservation of the fulcrum of the mandible as near the normal joint as surgical judgment decrees feasible.

3. Raw surfaces of bone created by ostectomy should be covered.

4. Proper consideration and protection of vascular entities which are apt to be deviously routed in and about a morphologically altered and enlarged condylar head is essential. A seldom mentioned vessel, the masseteric artery, can be troublesome.

5. The submandibular approach offers a safe and adequate access to the area for joint reconstruction plus the opportunity for a complete visual survey of the changed articular area, the coronoid process, and the entire height of the ramus.

REFERENCES

1. Baer, W.: Arthroplasty with the aid of animal membrane. Am. J. Orth. Surg., *16:* 1, 1918.
2. Blair, V.: Operative treatment of ankylosis of the mandible. Surg. Gynec. & Obst. *19:* 436, 1914.
3. Boyd, H. B.: Chapter XVIII in *Campbell's Operative Orthopaedics*., 3rd ed. C. V. Mosby Company, St. Louis, 1956.
4. Braithwaite, F., and Hopper, F.: Ankylosis of the temporomandibular joint. Brit. J. Plast. Surg., *5:* 105–121, 1952.
5. Eggers, G. W.: Arthroplasty of the temporomandibular joint in children with interposition of tantalum foil. J. Bone & Joint Surg., *28:* 603–606, 1946.
6. Forrest, H. J. and Robinson, D. W.: Delineation of the parotid gland by *in vivo* staining. Plast. & Reconstruct. Surg., *20:* 311–314, 1957.
7. Georgiade, N., Altany, F., and Pickrell, K.: An experimetnal and clinical evaluation of autogenous dermal grafts used in the treatment of temporomandibular joint ankylosis. Plast. & Reconstruct. Surg., *19:* 321–336, 1957.
8. Ham, A. W.: *Histology*, 2d ed. J. B. Lippincott Company, Philadelphia, 1953.

9. KAZANJIAN, V. H.: *The Surgical Treatment of Facial Injuries.* The Williams & Wilkins Company, Baltimore, 1949.
10. LONGACRE, J. J., AND GILBY, R. F.: Further observations on the use of autogenous cartilage graft in arthroplasty of the temporomandibular joint. Plast. & Reconstruct. Surg., *10:* 238–247, 1952.
11. LONGACRE, J. J., AND GILBY, R. F.: The use of autogenous cartilage in arthroplasty for true ankylosis of temporomandibular joint. Plast. & Reconstruct. Surg., *7:* 271–287, 1951.
12. MIKULIEZ: Quoted by RISDON, F.: J. Am. Dent. A., *21:* 1933–1937, 1934.
13. MURPHY, J.: Arthroplasty for intra-articular bony and fibrous ankylosis of temporomandibular articulation. J. A. M. A., *62:* 1783, 1914.
14. PADGETT, E., ROBINSON, D., AND STEVENSON, K.: Ankylosis of the temporomandibular joint. Surgery, *2A:* 426, 1948.
15. PEER, L. A.: *Transplantation of Tissues,* Chap. 14. The Williams & Wilkins Company, Baltimore, 1955.
16. Quoted by RISDON, F.: J. Am. Dent. A., *21:* 1933, 1934.
17. RISDON, F. R.: Ankylosis of the temporomandibular joint. J. Am. Dent. A., *21:* 1933–1937, 1934.
18. SARNAT, B. G.: Facial and neurocranial growth after removal of the mandibular condyle in the Macacus rhesus monkey. Am. J. Surg., *94:* 19–30, 1957.
19. SARNAT, B. G., AND ROBINSON, I. B.: Surgery of the mandible. Plast. & Reconstruct. Surg., *17:* 27–57, 1956.
20. SICHER, H.: *Oral Anatomy,* 2d ed. C. V. Mosby Company, St. Louis, 1952.
21. VERNIEUL, A.: De la création d'une fausse articulation par section ou resection partielle de l'os maxillaire inférieur, comme moyen de remedier l'ankylose orale du fausse de la machoire inférieur. Arch. Generale de Med., V. Serie, *15:* 28A, 1860.

BOOK REVIEW

The Editors of THE AMERICAN SURGEON *will at all times welcome new books in the field of surgery and will acknowledge their receipt in these pages. The editors do not, however, agree to review all books that have been submitted without solicitation.*

The Pathology and Surgery of the Veins of the Lower Limb. By HAROLD DODD, CH.M., AND FRANK B. COCKETT, M.S., Livingstone Ltd., Edinburgh and London, 1956; The Williams & Wilkins Company, Baltimore.

This is a book for the student and intern to study thoroughly and digest carefully. It is, in this reviewer's opinion, the best book available on this subject. It is written with the pathologic physiology of the veins of the lower limb clearly in mind. The physiologic explanations are fundamental and lucid in all details. The surgical measures to correct the various venous disorders follow logically and are carefully explained.

The practical aspects of the subject are never lost sight of. The young trainee surgeon will find it especially valuable, for as the authors state in their preface, "no finer training ground for surgery is to be found than in dealing with venous conditions. The diagnosis of the exact venous fault needs clinical skill and thoroughness. The operative procedures though often considered trivial are actually a testing exercise in exact dissection and good surgical technique, and when mastered largely overcome the difficulties of more extensive procedures."

The subject matter is divided into three parts. Part I covers the history, anatomy and physiology, with adequate photographs and illustrations that form the basis for the clear understanding of the pathology and surgery of the superficial veins, which constitutes the subject matter of Part II. The chapters on diagnosis and treatment are exceptionally well done and the illustrations are complete and thorough. The student should have no difficulty understanding the simple tourniquet testing for incompetent saphenous veins and the important communicating veins. The basic idea of therapy is quoted, "In fact the surgical aim in venous defects and their complications is to diagnose the site of the high pressure 'leak' from the deep veins into the superficial veins, and to close it by ligation at its source."

Part III has to do with the pathology and surgery of the deep and communicating veins. It does a remarkably thorough job of discussing the role of thrombosis in the development of the post-thrombotic syndrome (the chronically swollen leg), the physiology of venous ulcers and the very important management, both nonsurgical and surgical of the disabling and all too common chronically swollen leg. It is the last named entity that seems so universally misunderstood and mistreated.

The reviewer heartily concurs in the authors' handling of this subject but disagrees somewhat with their recommendations for the management of the white leg or acute femoroiliac thrombophlebitis. The authors recommend only bed rest in the Trendelenberg position for this serious complication.

This book should reawaken the need for more adequate understanding and more satisfactory therapy for the many patients who suffer from the effects of varicose veins and venous hypertension in the legs. It is an indictment of our teaching when so many of these patients have results that are unsatisfactory or are even made worse by inadequate or inept therapy.

As Linton states in the foreword of this book, "This is especially true since the majority of the disease complexes are curable if the proper operative treatment is performed. The poor operative results are due to: I—Failure of the profession to understand the basic pathologic physiology of these venous disorders. II—These surgical patients are apt to be cared for by the youngest and least experiences members of the surgical team because the senior surgeons cannot be bothered with the tedious, time consuming type of operative procedures necessary to obtain satisfactory results. III—More than usual postoperative care and follow-up of the patient is necessary for the best results because the venous conditions of the lower extremities represent chronic ailments from altered venous physiology."

RAYMOND M. CUNNINGHAM, M.D.